THE NOVEMBER SCIENTIFIC MONTHLY

Edited by

J. McKEEN CATTELL, F. R. MOULTON AND
WARE CATTELL

CONTENTS

PUBLISHED BY THE SCIENCE PRESS
LANCASTER, PENNSYLVANIA
FOR THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
SMITHSONIAN INSTITUTION BUILDING, WASHINGTON, D. C.

NEW BOOKS OF SCIENTIFIC INTEREST

Astronomy, Maps, and Weather. C. C. WYLIE. Illustrated. x + 449 pp. 1942. Harper.

This book is designed primarily to meet the needs of the Army Air Corps Flying Training Command. Discussed are such subjects as the celestial sphere, telescopes, the earth and its motions, clouds and weather forecasting, maps, time, celestial navigation, the moon, planets, comets, sun, stars, etc.

Strategic Materials and National Strength. H. N. HOLMES. Illustrated. v + 106 pp. $1.75. 1942. Macmillan.

Dr. Holmes discusses every sort of material—from metals to concentrated foods—as to their abundance, substitutes now in use and what substitutes research may discover in the future and how other nations coped with shortage problems similar to ours.

Sensation and Perception in the History of Experimental Psychology. E. G. BORING. Illustrated. 644 pp. 1942. D. Appleton Century.

The background and evolution of modern psychology of sensation and perception is the subject of this volume. Introductory material covers the general theory of sensation and the physiology of sensation; succeeding chapters take up individual sensibilities in greater detail.

Scientists Face the World of 1942. K. T. COMPTON and others. 80 pp. April, 1942. $1.25. Rutgers.

Dr. Compton discusses the various fields of science in general as they exist today. Dr. Vannevar Bush's chapter is on biological engineering; Dr. R. W. Trullinger discusses agricultural engineering. Commentaries on the three essays are contributed by three other scientists.

We Need Vitamins. W. H. EDDY, G. G. HAWLEY. 102 pp. $1.50. 1941. Reinhold.

This book attempts to give an understanding of the vitamins—as to what they are, their chemical and physical properties, the determination and expression of their potency, their effect on the human body and how it is accomplished, the amount needed by man daily, and the foods in which they can be found.

The Vertebrate Eye. G. L. WALLS. Illustrated. xiv + 785 pp. $6.50. August, 1942. Cranbrook Institute of Science.

The vertebrate eye and its adaptive radiation are discussed in three main sections: the fundamental background information, the environmental reasons for evolutionary changes, and the history of the eye traced from the lowest living vertebrates to the highest.

Biological Symposia. Vol. VIII. R. REDFIELD, ed. v + 240 pp. $2.50. 1942. Jaques Cattell.

A discussion of the levels of integration in biological and social systems form the basis of this symposium. The transition from unicellular to multicellular individuals; societies of insects, vertebrates as a whole, monkeys, apes and man are among the aspects treated.

The Pigeon. W. M. LEVI. Illustrated. xxxii + 512 pp. $10.00. 1941. R. S. Bryan.

The author presents for those who, like himself, find relaxation and stimulation in the hobby of pigeon-raising, a book which covers such topics as the relationship of pigeon and man; breeding and care, anatomy, physiology, genetical variations, behavior, etc. Over 600 pictures and diagrams illustrate the text.

Plain Words About Venereal Disease. T. PARRAN, R. A. VONDERLEHR. xi + 226 pp. $2.00. 1941. Reynal and Hitchcock.

A straightforward presentation of the present-day situation concerning venereal diseases is given in this book. The reader is told how the national program for venereal disease control made headway until war conditions set the stage for wholesale spread of the diseases.

The Story of Everyday Things. A. TRAIN, JR. Illustrated. xii + 428 pp. $3.50. 1941. Harper.

This is the story of houses, furniture, food, clothes, transportation and communication. It is also, to a certain extent, the story of agriculture, handicraft, and industry, community life and the life of the intellect, and amusements.

Gardner's Handbook. L. H. BAILEY. Illustrated. 292 pp. $1.49. 1941. Macmillan.

The object of this gardening manual is to provide a source of general information on flowers, shrubs, vegetables and fruit, intended for the enlightenment of the amateur gardener. The topics discussed are in alphabetical order, since the book is prepared as a reference book for practical gardening.

Doctor Wood. W. SEABROOK. Illustrated. xiv + 335 pp. $3.75. 1941. Harcourt, Brace.

This is a biography of Dr. Robert W. Wood, professor of experimental physics at the Johns Hopkins University. It tells of his youth as well as his work as an experimenter in the physics of light. It relates his varied experiences, including his hobbies as a scientific criminologist and exposer of scientific frauds.

The Doctors Mayo. H. B. CLAPESATTLE. Illustrated. xiv + 812 pp. $3.75. December, 1941. Minnesota.

This is a biography of Dr. William Worrall Mayo and his sons, Drs. William and Charles Mayo. It is a picture of a hundred years of medical progress, beginning with a small-town practice on the American frontier and ending with an international institution.

Taboo. H. WEBSTER. xii + 393 pp. $4.00. 1942. Stanford.

This treatment of the taboos of primitive societies includes their ethnographic, historical and psychological aspects, but the author's main concern has been to show how important a place taboos hold in the cultural evolution of mankind. The customs considered here are mostly of unknown origin and antiquity.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1942

BIOLOGICAL ADAPTATION

By THEODOSIUS DOBZHANSKY

PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY

ORGANISMS are said to be adapted to their environment, because they are built and act in ways which enable them to survive and to propagate their kind in the environment in which they normally occur. To an observer, a living being seems to be designed to attain the goal of survival and reproduction; it appears to strive not only to retain but to expand its hold on the environment. Most biological phenomena display an apparent purposefulness of a kind which we do not perceive to exist in inanimate nature. The concept of purposefulness belongs, however, to the realms of human affairs, of metaphysics and of religious philosophy; it has not so far justified itself as a tool of discovery in the natural sciences. A biologist must, if he can, reduce this concept to terms which are capable of serving as such tools. The difficulty of this task is formidable; it has not been completely accomplished, despite the fact that some of the greatest minds in biology have devoted their efforts to the solution of the problem of adaptation. The present status of this problem is outlined in the following paragraphs.

I

When a problem is very difficult, attempts are usually made to dodge it by denying its existence. Such attempts are not as illegitimate as they seem: many a scientific "problem" of bygone days has been shown to be spurious. This is, however, not the case with adaptation. It has been suggested that the alleged adaptations are mere anthropomorphic judgments, and that it is enough to describe how organisms are built and are functioning without imputing to their structures and functions any kind of aim or purpose. Unfortunately, this "solution" of the problem of adaptation is akin to the behavior of the proverbial ostrich hiding its head in sand. The adaptability of life is too evident to be dismissed so lightly, and it is not sound practice to restrict scientific description within set bounds. Consider, for example, these facts: when we ascend high mountains the composition of our blood changes in such a way that our toil is made easier; when our body is invaded by germs, it reacts in a manner which destroys or at least restricts the spread of the invaders; desert plants possess a whole retinue of devices which prevent excessive evaporation of water, while plants growing in moist places are usually less well protected from desiccation. Indeed, one could describe these and thousands of similar facts without reference to their bearing on the preservation of the existence of individuals and strains, but what useful purpose would be accomplished by this limitation?

Curiously akin to the view which disposes of the problem of adaptation by ignoring its existence is the assumption that purposefulness is an intrinsic prop-

erty of living matter. Both views attempt to settle the question by a kind of fiat. At any rate, since no organism is perfectly adapted to living in all environments and in all contingencies, the purposefulness of life is evidently incomplete. Adaptation is not something given to the organism once and for all time. In the process of evolution the harmony between the organism and its environment is constantly lost and recaptured, and the acquisition of this harmony is never safe or final but requires a continuous exertion on the part of the organism.

II

Up to the present, only two types of scientifically articulate explanations of organic adaptation have been advanced. They are known as the Lamarckian and the Darwinian types, respectively. Their essence and their contrasting features can be stated very simply. Lamarckism supposes that evolutionary changes are adaptive from the time when they originate; that the changes arise in response to the exigencies of the organism's existence; that these changes appear first in the body or in the mind, and only subsequently are fixed by heredity. The basic assumption of Darwinism is that changes originate in the hereditary materials, owing either to forces residing in these materials themselves or induced there by the environment. As they arise, the changes have no intrinsic relation to adaptation: some of them may be harmful, others neutral, and still others useful to their carriers. Adaptations become established owing to the retention of only or mostly those changes which increase the probability of survival or of reproduction of their possessors.

Lamarckism has run into many difficulties, and it continues to exist at present only on the fringes of biology, although it seems to have caught the fancy of some philosophers and speculative thinkers. The principal difficulty of Lamarckism is that it fails to explain why the need for a certain modification of some organ should produce such a modification. It is well known, of course, that repeated use of many organs, *e.g.*, of muscles, strengthens them, while sustained disuse weakens them. These effects of use and disuse are corollaries to physiological mechanisms which regulate the food supply to and the removal of waste products from functioning organs. The existence of such regulatory mechanisms should not, however, be taken for granted; they constitute most important adaptive attributes, and their origin demands an explanation. Furthermore, many adaptive reactions can be described only very loosely in terms of use and disuse. For example, a certain portion of the sun's spectrum induces formation of pigment in the human skin which prevents the penetration of the rays injurious to the internal organs. This is the tanning reaction of the skin which is known to furnish protection against sunburn. How has such an adaptive reaction become established in man's ancestry? The keen analytic mind of Lamarck saw the problem very clearly; Lamarck appealed to psychic phenomena as the primary source of adaptability. This part of Lamarck's theory (psycholamarckism) has baffled his successors (mechanolamarckists) to such an extent that the latter prefer to gloss it over with silence. It is an oversimplification to say that according to Lamarck an organism changes because it wants to do so, but in any case the nature of the supposed connection between mind and adaptation is utterly obscure. As to the mechano- or neolamarckists, they are, in effect, taking for granted the basic fact of adaptability which they pretend to explain.

The difficulties of Lamarckism do not end here. In order to become an integral part of the species, an evolutionary change must become hereditary. The supposition that changes resulting from use and disuse of organs are eventually

established in heredity is known as the hypothesis of inheritance of acquired characteristics. This hypothesis was subject to so much dispute in the early part of the current century that in the popular mind it has become synonymous with Lamarckism itself, although Lamarckism is a theory which is much deeper and broader than this hypothesis. Yet, it is an essential part of Lamarckism. Not many scientific hypotheses have been so widely and so persistently misunderstood as that of the inheritance of acquired characteristics. The problem is, however, simple enough. The question at issue is as follows: can changes appearing in the body in response to environmental stimuli induce *corresponding* changes in the hereditary materials? The correspondence of the changes is the crux of the whole matter. Take again the example of the tanning reaction of the human skin. The pigment in the skin appears in response to sunlight. Heredity is transmitted through the sex cells, or, more precisely, through the chromosomes contained in these cells. Will the presence of the skin pigment so influence the materials composing the chromosomes that in the offspring of the modified individual a greater amount of the same pigment will be deposited than in the ancestor before the latter was subject to the rays of the sun? It is conceivable that physiological changes produced in the body by the deposition of the pigment in the skin might somehow upset the hereditary materials, and might lead to the appearance of hereditary changes in all sorts of organs and functions, *i.e.*, to a general increase of the mutability. But even if such outbursts of mutability were observed (and they have not been observed), the result would tell us nothing about the inheritance of acquired characteristics. The hypothesis demands that acquired changes in the skin color be reflected in those parts of the hereditary materials which determine the skin color of the offspring.

It is fair, I think, to sum up the present status of the hypothesis of inheritance of acquired characteristics as follows. Experiments set up to test the possibility of such inheritance have generally given unequivocally negative results; the few alleged positive instances have not stood the test of critical scrutiny and repetition. This imposes such a strain on the theory that Lamarckists are forced to withdraw to a position which removes the whole question from the realm of the experimental method. It is pointed out, quite justly of course, that experiments involve of necessity relatively short time intervals. Nature has at its disposal incomparably greater time periods. May be, then, acquired characteristics can be inherited after all?

This position is formally unassailable, but no amount of tergiversation can conceal the fact that it is sterile as a working hypothesis. It may also be noted that the hypothesis of inheritance of acquired characteristics implies the existence of a very intimate one-to-one relationship between the body parts and characters on one hand and the discrete particles (genes) representing them in the sex cells on the other. Although the exact interrelations existing between genes and characters are as yet very little understood, biology has been veering away from the crudely preformistic notions according to which the genes borne in the sex cells are like diminutive vestiges of the organs of the adult body. The full import of this consideration is not realized by certain philosophers who profess Lamarckistic sympathies. The road from gene to character need not be a one way street: genes in the sex cells may, perhaps, be influenced by the body carrying them. The problem is how the genes react to influences emanating from the body periphery, and at

present it seems very improbable that identical changes are induced in both.

III

Since Darwin, Darwinism has undergone a complex development and a thoroughgoing modification. Darwin himself had accepted Lamarckism as a sort of subsidiary to his own theory. Neodarwinism, especially in its most brilliant representative, Weismann, led to elimination of all traces of Lamarckism and to erection of the purest "Darwinian" system of views. The period of neodarwinism may be said to have ended with the rise of experimental studies on heredity and variation (genetics). Space does not permit us to follow even briefly this evolution of Darwinism. Our purpose is rather to sketch the most essential parts of the modern system of views, which, if a designation is wanted, may perhaps be labelled inductive Darwinism.

The evolutionary process, of which adaptation is a part, may be likened to a factory having three divisions or levels on which different parts of a manufacturing process are carried out. On the first level the raw materials of evolution, that is the inheritable variations, are produced. Hereditary changes arise owing to forces acting from within or impinging from outside the body of a living individual. Availability of heritable variation is, however, not in itself sufficient to accomplish either evolution or adaptation, just as presence of raw materials in a factory does not insure the appearance of a finished product. Uncontrolled variation would produce a chaos of freaks rather than adaptive changes. The processes which combine the heritable variants into organized systems of traits take place on the second level. Here, then, the raw materials are shaped to become functional forms. Natural selection combines the hereditary elements into the integrated complexes which characterize races, species, or other biological groups adapted to the environments in which they live. Finally, the third level concerns the development of reproductive isolation between incipient species. Reproductive isolation (differences in the mating habits, inviability or sterility of hybrids, etc.) prevents species from exchanging portions of their hereditary endowments, and thus guards against disintegration of the organized adaptive systems formed on the preceding level. In terms of our factory allegory, a sort of packaging of the finished products is accomplished on the third level. It must, of course, be kept in mind that the distinction of the above three levels is made for analytical purposes only, and that in reality the three levels are interdependent.

IV

Here we must make a digression to state certain fundamental principles which ought to serve as a basis of any discussion of adaptation and evolution. For the sake of brevity biologists say simply that this or that character is or is not inherited. But a "character," such as color, size or shape of a certain organ or of the whole body, is merely an outward sign of some physiological process having taken place during the development of the organism. What is really inherited is not a character but the kind of response which is evoked by the environmental stimuli in the living organism. The appearance of an individual (its "phenotype") is determined by interaction between its heredity (its "genotype") and the environment in which the development is taking place. To illustrate: the skin color in man is said to be an inherited character; but it is generally known that the color of our skin depends upon external conditions, such as exposure to sunlight. Human stature is also inherited; yet, an individual grows taller or shorter depending upon diet, mode of life during childhood

and adolescence, the diseases suffered, etc. What is meant by inheritance of skin color and stature is that a given hereditary constitution will produce a certain skin color and a certain stature in a given environment. Different genotypes in the same environment may result in different skin colors and statures; the same genotype in different environments may or may not give different skin colors and statures.

In a given environment, certain genotypes may produce characters which are beneficial to their carriers, and will enable the latter to survive and to leave offspring. In the same environment, other genotypes may be unfit for survival. The general fitness of a genotype, its adaptive value, is evidently a function of its response in different environments. The adaptation may be a specialized one: an organism may react purposefully to the stimuli emanating from only that particular environment in which it normally occurs. A more generalized adaptation permits the organism to survive and to reproduce in a wide variety of environments. Thus, some insects require for food a definite species of plant or a definite kind of prey; other insects are more nearly omnivorous. Sumner and Sargent have shown that a certain species of fish found in warm springs in Nevada may survive for some time in springs of normal temperature, although its relative found in the latter is killed in the warm springs. An ideal adaptation would permit the organism to survive in all environments. Such a paragon does not exist: man's response to environments is doubtless the most effective one which has been evolved on earth and possibly in the Cosmos, but it falls far short of the ideal.

The variety of adaptive responses which an organism is capable of producing is great. We have already mentioned several such responses in man: the tanning reaction of the skin, changes in composition of the blood at different altitudes, reactions of the body to invasion by disease-producing germs. It is impossible to tell which of these responses are more and which are less important: that obviously depends on the environment. But it is fair to say that the adaptive value of a genotype is a function of all these responses.

The mechanisms which transmit heredity from parents to offspring can not be described here. Suffice it to say that modern biology has firmly established the fact that the hereditary materials are not a continuous mass but the sum of more or less discrete particles known as genes. Borne in the chromosomes of cell nuclei, the genes are independent in that in the process of variation they may change one by one (see below). The genes of an organism constitute its genotype and determine the response of that organism to the environment. The subtle relations which exist between separate genes and separate "characters" need not be discussed here, but it is very important to realize that the adaptive value of a genotype is determined by all the genes acting in concert. To put it differently, a functional genotype is not simply an array of genes each of which performs its function independently of the others. A genotype is an exquisitely adjusted system, in which the genes are closely comparable to separate workers tending an assembly line in a factory. Alteration or deletion of a single gene may modify some of the organism's responses to the environment, while other responses may or may not be left unchanged. Nevertheless, the adaptive value of the whole genotype very frequently depends on the behavior of a single gene. Furthermore, the adaptive value of a combination of genes is not predictable on the basis of the knowledge of the effects of each of these genes taken singly. Thus, the gene A may be favorable in combination with B but unfavorable in combination with C, while the gene D may be favorable with B and C

but not with A. Hence, evolution and adaptation may involve not merely a substitution of a gene here and a gene there but a change of the whole structure of the genotype. This is analogous to the thorough change which must be made in an assembly line if it is to produce tanks instead of automobiles or *vice versa*.

V

Hereditary variants arise chiefly, if not exclusively, through discrete steps termed mutations. Some mutations, such as the origin of a sheep with legs resembling those of a dachshund, were known to Darwin, who considered them too rare and too drastic to be of importance in the process of adaptation. De Vries, the founder of the mutation theory, also thought that mutations produce great departures from the ancestral type. As more mutations were found in diverse organisms, it became clear that the extent of changes induced by mutations varies greatly. Not only are the alterations produced by some mutations so small that refined techniques are required for their detection, but small mutations prove to be much more frequent than large ones. The common "fluctuating" variability, such as the variation of the human stature, body proportions, hair color, etc., can be described as compounded of mutational elements. However, regardless of size, the mutational steps are discrete: no intermediates between the original and the mutant conditions can be detected. It is this discreteness rather than the extent of the change that characterizes the mutational variability. Most, although not all, mutations represent changes in a single hereditary element, a gene.

The frequencies with which genes mutate in different organisms, and those with which different genes mutate in the same organism, are variable. Haldane infers that the gene for haemophilia (bleeding) in man mutates once in about 50,000 life cycles; Timofeeff-Ressovsky estimates that in the fly *Drosophila* between 2 and 3 per cent. of the sex cells contain newly arisen mutants in one or more genes. All sorts of changes arise by mutation: alterations of superficial and of anatomical structures, of physiological and psychic (reflexes, habits) functions, modifications localized in a small part of the body and upsets of the basic developmental patterns. Mutations occur almost always singly, among masses of unchanged representatives of a strain.

A mutation gives rise to a new hereditary variant, a mutant. The response of a mutant to the environment is different from that of its ancestor. From the standpoint of adaptation, the value of a mutant depends upon the fitness of its reaction to the environment for survival and reproduction. Several possibilities present themselves. A mutant may be neutral, *i.e.*, it may survive and reach the reproductive stage of the life cycle as often as the original type, the average fecundity being the same as in the original type. Neutral mutants are always present in populations of living species. For example, practically all human races and strains are mixtures of several hereditary types differing in the composition of their blood (the "blood groups"); as far as known, the blood groups are equivalent with respect to their survival values; the genes responsible for the blood groups are adaptively neutral. A mutant may, however, survive more frequently or may leave a more numerous progeny than the original type in the same environment in which the latter normally occurs. This is a favorable mutant, and it will tend eventually to supplant the original type. Still other mutants may respond to the environment in which the species normally lives in a manner less favorable than the original type does. The mutants may, however, have an advantage over the ancestral type in some environment or environments in which the species occurs but

rarely or not at all. The species will, then, be split into two or more races, each a master of its special domain. For example, Banta and Wood have observed a mutant in the water flea which survived with difficulty at the temperature at which the species normally lives, but which was able to exist at a higher temperature fatal to its ancestor. Many plant species are differentiated into races living in valleys on one hand and in high mountains on the other; the plants of the mountain races suffer if transplanted in the valley, while the valley plants die off if planted in mountains. Finally, a mutant may respond unfavorably in all existing environments, or at least in all environments which the species is able to reach. Such a mutant can not become established anywhere, but, since it may continue to arise from time to time by mutation, it will recur sporadically as a phase, an aberration, or a monstrosity. Genes producing pathological effects, such as the above-mentioned haemophilia mutants in man, belong to this class.

The foregoing paragraph contains a condensed statement of Darwin's theory of natural selection in its modern form. Natural selection is at the same time the judiciary and the executive agency of the environment. Every genetic variant is evaluated according to the fitness of its reactions for securing or retention of a foothold in some niche of the environment. The fit variants are multiplied, and may become established to the exclusion of all others. The unfit ones are reduced in frequency or eliminated. It should be noted that there is no absolute minimum degree of usefulness which a variant must possess before natural selection comes into play. No life-and-death utility is needed. If the offspring of two variants survive in a ratio 999 : 1000, the frequency of the fitter variant may increase in time.

The early protagonists of natural selection have in their crusading zeal grossly exaggerated the ferocity of the struggle for existence which promotes adaptation. An unsuccessful mutant need not be immediately pounced upon and stifled by its competitors from among the members of the same species. The elimination of unfavorable genotypes can be described more adequately as taking place through non-perpetuation rather than through outright destruction. It is, of course, true that, as first pointed out by Malthus, only a fraction, and frequently only a small fraction, of the offspring produced by any one species reaches adulthood. But these Malthusian hecatombs are for the most part blindly accidental rather than differential or selective. The differential survival which is the keystone of natural selection is a more subtle process.

Since evolutionary changes taking place in nature are based mostly on small differences in the survival values of the competing variants, the process of transformation is in general too slow to be noticeable within the limits of a human lifetime. Evolutionists were constrained to acknowledge that evolution has not been observed directly but only inferred on the basis of circumstantial evidence. Although major transformations can still be neither witnessed in nature nor reproduced in the laboratory, some evolutionary changes have been recorded. The splendid work of Quayle, Dickson and their colleagues has demonstrated that new races have developed and are developing in certain scale insects in the citrus orchards of California. These races show a greater resistance than the original types to fumigation with hydrocyanic gas which is regularly practiced in the citrus groves for the purpose of pest control. Since 1913 the appearance of cyanide resistant races has been recorded in at least three species of scales, and in one of them the resistance is known to be due to mutation in apparently a single gene. There is no doubt that the spread of the resistant races is due to natural selection, the fumigation

with hydrocyanic gas being the selective factor. There is a growing body of evidence of a similar kind in other organisms as well: emergence of a race of the coddling moth adapted to walnut instead of to apple, changes in the composition of populations of certain rust fungi and of a species of the flies *Drosophila*.

VI

Natural selection causes the spread and establishment of favorable variants and elimination of unfavorable ones. However, it continues to operate only so long as there is available a store of heritable variants which differ in their reactions to the environment and in adaptive value. Natural selection merely selects variants from the accumulated stock, but it does not itself produce new variants; natural selection does not induce mutations. This is the basis of the oft-repeated assertion that natural selection creates nothing new and is a conservative factor. This assertion is true in a sense, but it is highly misleading unless its precise meaning is understood very clearly.

First of all, how great is the stock of variants accumulated in natural populations? As pointed out above, the transmission of heredity from parents to offspring is accomplished through particles termed genes. Exactly how numerous are the genes is in no case known, but estimates for organisms as complex as an insect range in thousands. Each gene is capable of giving rise by mutation to several modifications. Now, the mechanism of sexual reproduction, the corollary of which are the laws of Mendel, operates to produce all possible combinations of the available diversity of genes. Assume that a pair of parents differ in three genes—one parent being ABC and the other abc. Among the grandchildren there will appear the gene combinations ABC, ABc, AbC, aBC, Abc, aBc, abC and abc. Every gene combination has its own response to the environment, and hence its own adaptive value. Some of these combinations, for example, ABc, AbC and abc, may be favorable and the remainder unfavorable. The favorable gene combinations must arise before they can be judged by natural selection; mutation produces gene variants, but sexual reproduction is the magnificently efficient mechanism which produces gene combinations. This role of sexual reproduction was not at all sufficiently appreciated in Darwin's time.

Sewall Wright points out that if one makes the very conservative estimate that there are 1,000 variable genes each modifiable by mutation in 10 different ways, the number of possible gene combinations turns out to be 10^{1000}. This figure is fantastically large; it has no analogue in the world of reality (the number of electrons and protons in the visible universe is thought to be of the order of 10^{300}). Indeed, nothing can be more certain than that only a very small fraction of the potentially possible gene combinations have ever been realized in nature and tried out by natural selection. Yet the number of existing gene combinations is also enormous—it is virtually certain that, for example, every individual human being (identical twins excepted) possesses a gene combination not present in any other individual now living or having lived. When applied to an agent which selects or rejects variants from so colossal a store as this, the adjectives "creative" and "conservative" assume quite other than their usual meanings.

The uniqueness of every human individual we recognize as manifested in his appearance, and take it largely for granted. Yet the hereditary variability is much greater than its external manifestation might lead us to believe. Certain genes (Mendelian recessives) may be carried in the hereditary materials of an individual in a concealed condition, but their external manifestation may be only delayed and may come to light in the offspring. Recent studies have shown

that natural populations of sexually reproducing species harbor a hitherto scarcely suspected wealth of concealed hereditary variability. A closer examination of this concealed store of variability shows that its constituents are mostly harmful to the organism if permitted to manifest their action. The sexual reproduction is, however, incessantly shuffling and reshuffling the gene elements in this store. Ever new gene combinations are being formed. Genes which are deleterious in some combinations may be favorable in other combinations. Variants which are incapable of survival in one environment may be suitable in other environments. Moreover, the environment is seldom static not only on geological but even on human time scale. A trait useful in New York may be utterly useless in a tropical jungle; a peculiarity superfluous to-day may be valuable tomorrow. Certain observations on natural populations of flies belonging to the genus *Drosophila* suggest that the adaptive plasticity of living species has been much underestimated. Changes adjusting a species to various phases of its environment, even though these phases may be of a very temporary nature, are taking place continuously, and their speed is appreciable enough to be observed directly.

VII

Much has been written about the improbability of "chance" producing adaptive modifications. Can adaptive structures and functions arise by summation of the occasional useful variants? The difficulty appears to be especially formidable where complex and beautifully balanced organs, such as the human eye, are concerned. It is equally difficult to visualize the origin of the physiological correlations and interrelations between various organs and functions of the body which are accomplished, as we know or suspect, through an intricate system of chemical messengers and nervous stimuli. Could, for example, the series of physiological changes taking place in the woman's body in connection with pregnancy and childbirth have developed by natural selection combining numerous mutants? And what about the unbelievably complex structure of the human brain? The problem is aggravated further if one compares the systems found in different organisms, say a fish and a mammal. For it seems that each of these systems is balanced so delicately that it can function only as such —intermediate systems or systems combining the features of the two would be absurdly incoherent and unfit to survive.

The following analogy, or its variants, have been suggested to illustrate the above difficulty. Imagine monkeys shaking boxes containing printer's type; could the letters ever arrange themselves by chance to produce Dante's Divine Comedy? At first sight, this difficulty, which had already perplexed Darwin, appears wellnigh insuperable, so much so that it has made all forms of Darwinism unacceptable to many thinkers in and out of biology. There is no use pretending that this difficulty has been satisfactorily solved. A way toward its solution may, however, be discerned. Two main considerations must be brought forward in this connection. First, we have become aware of the existence in nature of a trial and error mechanism on a scale scarcely suspected in Darwin's and even in Weismann's times. Sexual reproduction is a marvelously efficient "shaker" of the biological letters. Furthermore, and this is the main point, the "monkey analogy" misconstrues the situation in that it overlooks the historic aspect of the process of adaptation.

Organs and functions have not arisen at once in the state of the relative perfection which they now exhibit. Mutation and selection have not created them overnight from inorganic substances. They have developed from humbler beginnings, from simpler organs and functions. Yet, these ancestral organs and

functions had an adaptive significance to their carriers. Surely the organisms of the past were just as capable to survive in their environment as the now living organisms can in theirs. The progenitors of the living beings of to-day possessed genes and responded to their environments through their organs and functions. Returning to the "monkey analogy," the shaking of the printer's type need not produce the Divine Comedy complete to the last letter. In so far as this analogy is at all fit to illustrate the process of biological evolution, it should be stated as follows. A chance concatenation of letters had produced only the first verse, and as soon as that appeared the letters composing the verse were bound together. The second, third, and the following stanzas were formed and added to the first. Thus, the Divine Comedy grew and developed, the beauty of its parts as well as that of the whole design unfolding step by step. Seen in retrospect, the process reveals the inspiration of the poet, although each verse arose, if you will, by chance. A better analogy would be to compare organic transformation to the development of a poetic work from its inception in the poet's mind to the final stage in which we know it. Indeed, there might have existed many sketches and drafts of the Divine Comedy containing verses which were subsequently deleted but lacking verses which appear in the finished masterpieces.

It is, hence, only a very partial truth to say that inductive Darwinism builds its theory of adaptation on chance. Oddly enough, some of those writers who are most impressed by the difficulties of conceiving the occurrence of adaptive evolution under the control of natural selection make much greater appeals to chance in their alternative theories. Among the recent speculations, by far the greatest role is ascribed to chance in Goldschmidt's theory of "systemic mutations." Goldschmidt does not believe that summation of mutational steps could ever lead to anything greater than a few changes in the details of organization. Major evolutionary advances are ascribed to entirely hypothetical systemic mutations which produce in a single leap radically different organs and functions. The systemic mutants are characterized by Goldschmidt himself as "hopeful monsters" whose hopes are fulfilled very rarely. According to this theory, then, the Divine Comedy must appear almost complete, natural selection being able to make only minor corrections in the printer's proof.

The evolutionary transition from one integrated adaptive system, such as fish, to another system, such as mammal, presents difficulties on any theory yet proposed, since, as pointed out above, intermediate systems would seem to be poorly balanced. Indeed, some paleontologists believe that the beginnings of most major biological groups are conspicuously absent or rare in the geological record. Provided this belief is justified, we are forced to admit that evolutionary transition is sometimes a painful process, leading to a temporary eclipse of the group of organisms which is in the throes of reconstruction. This may have a profound biological significance. Modern genetics indicates that conditions most favorable for rapid evolutionary development may occur more frequently in species that are rare and broken up into numerous isolated populations than in very common and widespread species. It may be that the forms of life that are most successful on a given geological level are not the progenitors of the living beings dominating the next geological age. There may exist a kind of super-selection demanding that an organism passes through an eclipse if it is to inherit the world of to-morrow.

VIII

The magnitude of the store of hereditary variability available in nature and the great potentialities of the trial and error mechanism furnished by sexual

reproduction in conjunction with natural selection permit us to visualize the process of formation of adaptive genotypes. But the problem of adaptation is not yet solved thereby. Hereditary variants arise, as we know, by mutation. Mutations are frequently changes in a single gene (some mutations entail reduplications or losses of whole chromosomes or groups of chromosomes, but these kinds of mutations play, on the whole, a subordinate role in evolution, and we need not consider them here). Some gene changes may improve the adaptive response of the organism to its environment. Is, however, the need for a given kind of mutation somehow capable of producing that mutation? For unless the hereditary elements from which an adaptation could be constructed are available, natural selection is powerless to remedy the situation.

Neither the structure of the gene nor the nature of changes which genes undergo in mutation are sufficiently well known at present. Genes are particles borne in chromosomes of cell nuclei. They may be single organic molecules, or groups of molecules, or else a whole aggregate of genes constituting a chromosome may be a supra-molecular system the parts of which are somehow interdependent. A gene mutation is probably a chemical alteration taking place in a portion of a chromosome. Such alterations arise spontaneously from time to time in all organisms studied in the respect. The frequency of mutation may be increased one hundred fold or more by x-ray, by ultraviolet radiation, and perhaps by certain chemical treatments. But with the exception of certain transformations in the microorganisms producing some forms of pneumonia in man (pneumococci), we can not induce at will a given mutation in a given cell. The mutation process is not yet under human control. Mutations just happen.

The temptation to cut the Gordian knot is great—some biologists explicitly or implicitly assume that in nature the mutation process may somehow be directed by environmental influences into useful channels. Suppose, the climate of the country in which an organism lives grows colder; could this climatic change induce mutations improving the response of the organism to cold? Exposure of the human skin to sunlight results in an increase of the skin pigmentation; is sunlight likewise producing mutations which make the organism manufacture more and more pigment? It is pointed out that, since the causation of mutations is unknown, this possibility must be at least considered open. Unfortunately, what we do know about the mutation process belies this reasoning.

The existence of a biological function which a mutation might fulfill does not seem to induce that mutation. Mutations occur regardless of their potential utility. The profusion of species which once lived but became extinct attests the fact that the mutations which are necessary to maintain the harmony between an organism and its environment are not always produced. As to the possibilities in the realm of the unknown, we would do well to examine the implications of a theory before we agree to adopt it even for speculative purposes. Suppose that genes do respond to the impact of each type of environment by producing only certain mutational changes. The survival value of a mutant is determined not by the changed gene alone but also by its interactions with other genes present in the same organism. The adaptability of an organism depends upon its entire hereditary endowment. To assume that an organism responds to the demands of its environment by producing only or even mainly those mutations that specifically answer these demands would mean that the organism has a prescience of the future. This is tantamount to the assumption of an intrinsic purposefulness of the living matter. On closer examination the theory of adaptive directedness of mutations falls under its own weight.

Mutations are often said to occur by chance or at random. These epithets are justified only in so far as they imply that mutations are not inherently purposeful at the time of their origin. The survival value of a mutant is a function of the time and place in which it appears. Otherwise, the mutation process is controlled by the organization of the living matter in which the changes arise as well as by the physical environment. Although very little is known about these controls, the following facts are relevant. Some genes change by mutation more often than others. Thus, in the fly *Drosophila*, mutations changing the normal red eye color to white or to intermediate shades have been observed certainly more than one hundred times, while the origin of some other mutant types has been recorded only once. Timofeeff-Ressovsky found that in a certain strain of Drosophila the gene giving rise to the white-eyed mutation is more stable than in a certain other strain, and that in one strain this gene gives rise chiefly to eye colors intermediate between red and white while in the other most of the mutants are pure white. In rapidly developing organisms like Drosophila the general mutability is much higher per time unit (although not necessarily so per generation) than in the slowly developing human. This fact may, indeed, be considered an adaptation: with a mutability as high as it is in Drosophila man's chromosomes would be loaded with mutants within few generations.

One of the properties of genes which is known with certainty is that genes are self-reproducing entities. Any gene, if it is to persist from generation to generation, must be able to build a copy of itself from the materials available in the cell. Not all cell constituents are endowed with the capacity of self-reproduction. It may be that this capacity is confined to genes alone, and that the growth of the remainder of the cell is governed by the genes. However that may be, the freedom of mutational change is decidedly limited: unless a mutation results in a physical destruction of the gene, it must be a kind of change which does not deprive the altered gene of its ability to reproduce itself. Now, self-reproduction is, from a chemical standpoint, a very startling property. It must of necessity presuppose a very special, and as yet completely unknown, chemical structure. Thus, a gene is a body which must have arisen by a historical process which a biologist is tempted to call natural selection. The gene embodies, or at least shares in, the most fundamental, and yet frequently overlooked, attribute of the living matter: it carries its history within itself.

Viewing a living organism as the outcome of a historical process may help us to comprehend what is otherwise a mystery: how can what seems to be a blind chemical change in a gene lead to furtherance of the harmony between the organism and its environment? This problem is, after all, a part of a more general one: how can a living body be built of chemical substances? A living being is, in its physical aspect, a bundle of chemicals arranged in a certain pattern. But looked at from a biological angle, a living being is a system so designed as to be to a maximum degree attuned to its environment and able to perpetuate itself in the process of reproduction. Any change in this system must, in the last analysis, be physicochemical in nature. Yet, the components of the system as well as the pattern in which they are arranged are sequels of countless generations of natural selection and embodiments of the organism's history.[1]

[1] The writer takes pleasure in acknowledging the help received from Professors Jacques Barzun, L. C. Dunn, C. C. Epling, Selig Hecht, Miss A. M. Holz, Professors A. Mirsky, M. M. Rhoades, H. B. Steinbach and Mrs. Steinbach, who have read the manuscript of this article and suggested changes and improvements in presentation.

FOOD AND FITNESS

By Dr. A. J. CARLSON

FRANK P. HIXON PROFESSOR EMERITUS OF PHYSIOLOGY, THE UNIVERSITY OF CHICAGO

OUR country produces probably the greatest variety and quantity of good foods. Are we making the most of this resource for optimum health? For the last ten years we have been told that one third of the American people are ill fed, that these forty million American citizens suffer from malnutrition. Is this true? And if it is true, what are the reasons for it, and what can we do about it? In fact, very recently we were told much more. At the National Conference on Nutrition for Defense, held in Washington, D. C., a year ago, Dr. Thomas Parran, chief of the U. S. Public Health Service, said: "Studies of family diets by the Department of Agriculture in all income groups of the Nation show that one third of our people are getting food inadequate to maintain good health" and "less than one fourth of us are getting a good diet." If this is true, that makes it, not forty million, but about one hundred million Americans with an inadequate diet, from any and all causes. The question is: Is this true? These alarming claims for national malnutrition appear to be based primarily upon a series of surveys conducted by the Bureau of Home Economics of our Federal Department of Agriculture, assisted in some of the field work and statistical analysis by the Department of Labor. These surveys embraced some 4,000 urban and village families of various levels of income and some 2,000 rural families of varying levels of income, selected from representative regions of our country. The surveys consist in reports from these families as to how much money they spent for food, and what kinds of food were bought, and, in the case of rural families, how much and what kind of food they consumed from the crops on their own farms. These field investigators (some of them on WPA) had to take or did take the people's word for all these alleged facts. It is impossible to determine the degree of accuracy or honesty (accuracy as to memory) of whatever member of these families gave the facts or alleged facts to the enumerators.

Nor do the surveys indicate the amount of foods actually eaten or the amount of food wasted. The latter factor is probably not inconsiderable, particularly in the families of the higher income groups. I know of no statistics on this point, but on the whole, my experience indicates that the food waste at the table increases with the economic prosperity of the family.

On the basis of the kind and quantity of the food bought or grown on the farms, the Bureau of Home Economics estimated the diets of these families as excellent, good, fair or poor. We wish to point out that no physical or medical examination was made of the members of these families. Not even such a simple physical fact as the determination of the body weights of the people involved seems to have been undertaken. I can only express my great regret that the value of these statistics must so largely be left up in the air as regards evidence for good or bad nutrition in our country by neglecting such an obvious factor as medical evidence of the health status of these people concerned. Good medical examinations of members of around 6,000 families in our country does not seem a superhuman task. I feel certain that if competent medical men in the U. S. Public Health Service, in the Bureau of Home Economics of the Department of

Agriculture or in the Federal Department of Labor were not available, a suitable approach to national and state medical societies would have resulted in cooperation sufficient to carry out such a medical survey at little or no cost to the government. The surveys as conducted were made at considerable cost to our tax-paying citizens.

Is that the only evidence of national malnutrition? Do our hospital records, our mortality statistics, our medical examination of our young men for the Army and the Navy point to a nationwide malnutrition in America? Mortality statistics, even were they reliable, would only reveal extreme malnutrition. They would not tell us much about early stages of malnutrition. Between three and four thousand people are recorded as dying from pellagra (a disease due to an inadequate diet) each year. There is no recent rise in this category. Of course, there are many more people sick from pellagra than people who die from this disease, possibly as many pellagra patients as 100,000 in our country each year. Advanced scurvy is now almost unknown in the United States. Beriberi is somewhat less rare, especially if we include those cases due primarily to chronic alcoholism and consequent failure to eat enough good food. Rickets is not a killing deficiency disease. We may have anemia from too little iron in the diet; but lack of iron is just one of the many causes of anemia. So national mortality statistics fail to answer our question, but so far as they go, they do not point to a state of well-nigh universal malnutrition in the United States. And the same is true of records of our hospital admission. Of course, you may reply that doctors do not recognize early stages of malnutrition. Well, if physicians don't, are WPA workers and Washington politicians any more competent in this field? According to Colonel Rowntree, M.C., U. S. Army, the first 800,000 Army draftees of 1941 examined were on the average 67½ inches tall, or of the same stature as our 1917–18 Army draftees, but our 1941 draftees averaged 8 pounds heavier than those of World War I. According to General Hershey rejections of draftees on account of underweight are so far about the same as the rejection for obesity, or each around 4 per cent. So you see even the story of our draftees does not point to a universal and demonstrable malnutrition. According to the *Statistical Bulletin* of the Metropolitan Life Insurance Company, the average length of life as computed on the basis of mortality of the company's industrial policy holders in 1941 was 63.42 years. This is an all-time high for the sixty years that the company has recorded this information. This does not support the claim that one hundred million Americans suffer from malnutrition. But I am not willing to go all the way in supreme optimism, as does Mr. J. R. Hildebrand (*National Geographic Magazine*, March, 1942), who asserts that our "machine food age—born of roads, research and refrigeration—has made the United States the best-fed nation in history." We have the food to do it, had we the intelligence.

Well, what happens to us when we do not eat enough good foods? Can we know, without asking a doctor, when we suffer from malnutrition? And if we ask the doctor can he tell us when and what? The simplest situation is this: Assuming absence of chronic diseases, if an adult does not eat enough for energy needs he loses weight, if a child does not eat enough for energy needs he soon ceases to grow. Any layman can strip and step on the scales. The physical and mental impairments following prolonged inadequate intake of essential protein, essential fatty acids, essential inorganic salts and vitamins are more insidious. They can not at present be diagnosed even by the physician, unless they are well advanced, and by exclusion of many other

factors that may produce similar symptoms—such general symptoms as decreased physical and mental endurance, decreased appetite, etc. The anemias we encounter in the population are usually not due to too little iron in the diet. Nervous disorders and poor intelligence are very rarely due to vitamin deficiencies. The signs and symptoms of such dietary deficiency diseases as scurvy, rickets, pellagra, beriberi, "war" edema (protein deficiency) any up-to-date doctor can detect and eliminate. But no one (doctor or layman) can be sure in regard to the early stages of these dietary deficiencies. We have recently been told by a national committee of physicians, who should know, that one of the first signs of malnutrition is decreased appetite, and that laymen can diagnose their own state of nutrition by the state of their appetite for food. This is too good to be true. If it is true, and it is also true that one hundred million fellow citizens suffer from malnutrition, it is clear that the American appetite for good food is sunk, and that it probably will take something more potent than synthetic vitamin pills to restore it to a level of national safety.

This sounds discouraging, if not alarming, at least to laymen. Must our national safety and well-being in the matter of nutrition be thus left in the fog, pending further medical and nutritional research? Not at all. America is a paradise in the matter of abundance and variety of all the foods requisite for an optimum human diet. And if we are average normal men and women, we still have our primitive urges of hunger and appetite, notwithstanding recent published assertions to the contrary. How do you suppose our ancestors carried on, in the total absence of modern knowledge of food chemistry, vitamin requirements and the alleged necessity of "a pint of milk a day"? I do not think Sioux Indians got much milk from the wild buffalo. The American Indian had neither cows nor goats. And yet he carried on. It is evident that for the greater part of human history man did very well nutritionally by eating enough of all available varieties of natural foods, guided by his hunger and appetite. Nutritional safety lies in omnivorousness, in consuming, so far as possible, foods in their natural states, and, in the case of fruits and vegetables, eating some of them raw. Some of our malnutritions started with the processing, the refining and the "purification" of such foods as the cereal grains, modern milling processes shunting the most valuable part of these natural foods into the mouths of chickens, cattle and hogs. The cereal grains hold valuable proteins, vitamins and minerals. Human dietary safety on this front would seem to be: Go back to first principles—putting the whole grain into the flour and the bread. This can be done. We can learn to like it. There is no more "purity" or nutritional virtue in white bread than in white winter butter. I think we could learn to prevent the oxidative rancidity of whole grain flour. And until we have that problem licked, what is the matter with storing the wheat and milling the flour as we need it? I do not see any essential economic principle in storing the flour in place of storing the wheat. In my judgment, the recent addition of a little of the vitamins and minerals now milled out of the grain and singing peans of dietary salvation over this "enriched" flour and bread is not a sound policy either for to-day or tomorrow. Let us get back to first dietary principles on this front also. The whole wheat, rye or rice grain is one of our least expensive protective foods. On the whole we can trust nature as to the genuine nutritive elements in the whole grain—yes, trust nature further than the chemist and his synthetic vitamins. Recently, Professor Drummond (*Journal*, American Medical Association, March 7,

1942), the scientific adviser to the British Ministry of Food, voiced this reluctance to put the dietary safety of a nation on synthetic vitamins as a long-range policy. He thinks we must and should provide the natural vitamins in the natural foods. I stand on that platform, until we know a great deal more than we know to-day about foods and human nutrition.

How vital are vitamins? What happens when our breakfast, lunch and supper do not adequately balance with all the known vitamins every day in the year? The vitamins are vital. Even the kangaroo and the crow do not get on without them. They get all the vitamins required in their natural food. So did our ancestors. So could we. On an adequate abundance of natural foods we store vitamins in the body against weeks and months of vitamin scarcity. If we live mainly on such vitamin deficient foods as white bread, polished rice, fat salt pork, refined sugars, refined and hydrogenated vegetable oils, refined lard, etc., serious things happen to our health when our body stores of vitamins are depleted or nearly depleted. It should be obvious to all laymen that every meal every day does not need to be vitamin balanced. Our body stores take care of our urgent needs for weeks or months, unless we have already subsisted on the minimum for some time. It is a fact that an adult man in average good health can go without any food whatever for at least forty days, without showing any recognizable vitamin deficiency. At the end of a forty-days fast the man is considerably emaciated and more readily fatigued, but his appetite for good food is keener than ever. There is to-day entirely too much blarney and ballyhoo about synthetic vitamin pills. Under any and all circumstances these pills are said to give us the abundant life, including intelligence, mental stamina and moral conduct! The tragedy here is this: Few if any of the people who can afford to buy these pills need them, few if any of those who need them can afford to buy them. The consumer should insist that advertising of food conform to honest and factual education of adults in nutrition, for it is obvious that the consumer pays the freight of all food advertising in the increased cost of the advertised foods.

We are urged to drink milk, and to eat meats, eggs and vegetables for our needs of inorganic salts. Is that a good insurance? Is it enough? Can we get adequate mineral insurance at less cost through other foods? While it appears true that herbivorous mammals have sought "salt licks" for countless ages, and our forebears fought wars for possession of sea salt as their more sophisticated descendants now do battle for crude rubber and mineral oil, it seems obvious that except for the element iodine in restricted areas of the earth the dietary needs of minerals were efficiently met by the common non-purified, non-processed natural foods. So far as I know this would still hold true, except for the cooking of such foods as meats, fruits and vegetables and the habit of discarding the cooking water. To be sure the otherwise excellent natural food, milk, is so deficient in iron that an exclusive or almost exclusive diet of milk for weeks or months brings on an anemia due to the iron deficiency in the diet. How does the American dietary stand as to some of the essential mineral needs such as calcium, phosphorus, iron and iodine? The iodine deficiency in the States whose soil and water were depleted of iodine by the waters from ancient glaciers is now taken care of by putting the iodine back into our table salt. The iodine was there before our ingenious chemists learned to take it out. In so far as purification deteriorates our food, the science of chemistry does not serve man's welfare. Professor C. H. Sherman, of Columbia University, an outstanding expert on nu-

trition, has long held the view that the American diet is probably too low in calcium and possibly in phosphorus for optimum nutrition. This problem is complicated by the fact that a modicum of vitamin D is involved in the adequate absorption and utilization of calcium and phosphorus, particularly in the growth and maintenance of our bones. *Can not the possibility of a dietary danger in this field be met, universally and without cost, by adding a little calcium, phosphorus and iron to our table salt?* This should offer no insurmountable difficulties, and there is no evidence that a slight excess above actual needs of these minerals works any injury to our health. We are urged to eat milk for its calcium. Yes, milk is a good source for lime. But milk is a relatively expensive food, and even in our country, with a plethora of foods there is not enough milk to go around, at least as long as we insist on butter and cream for our table and turn so much of the valuable skim milk into channels other than human food. I think we should put a little lime, phosphorus and possibly iron into our table salt as a national insurance towards good nutrition. But I wonder how many vitamin B pills we must consume before we nurture sufficient intelligence to take this apparently rational step.

It seems clear that we do not know the extent of malnutrition in our country. But some malnutrition, especially pellagra, obesity, underweight, anemia, does prevail here. Why? The causes for the malnutrition that does prevail are both numerous and complex. Among these are: chronic infections, worry and mental strain, faulty dietary habits, ignorance as to what makes up an adequate diet, personal laziness, poverty, misleading food advertisements, denaturing of such staple and standard foods as flour (wheat, corn) and bread, possibly too great consumption of purified sugars and candy, waste of good foods, especially fruits and fats, etc.

Since man and his health constitute our most important natural resource, we must proceed without delay and with all the brains at our command to find better and more reliable methods to diagnose the signs and symptoms of *incipient dietary deficiencies.* Such knowledge will give us a clearer understanding of what constitutes an optimum diet for optimum health, so far as health is determined by diet alone. This, it seems to me, is a primary charge on the science of medicine, the science of biology, the science of chemistry. But we who labor in these fields will proceed faster along these lines, if we are encouraged by an understanding of the urgency and the difficulties in the problem and the cash cost of its solution on the part of all citizens.

Pending this greater scientific understanding as to human food needs for optimum health, these important things can and should be done now: (a) cleanse our present food and nutrition education of all fads, of all selfish commercial and myopic political propaganda; and (b) move our nutrition education from the ivory tower down to comprehension and appreciation of the common man. We have the brains and the cash to do it. Have we the will to carry on this hard task, when a possible superior health for all is the only goal, the only reward? I wonder.

NAVAJO SOCIAL ORGANIZATION AND LAND USE ADJUSTMENT

By E. R. FRYER

GENERAL SUPERINTENDENT, NAVAJO SERVICE, U. S. INDIAN SERVICE, WINDOW ROCK, ARIZONA

THE recent history of the Navajo people began eight years ago. Then, there was depression and drought. Wool and livestock prices had sunk to new lows. The demand for the semi-luxury items of Navajo rugs and silver had nearly vanished. The traders had extended credit to the limit of their resources.

Fortunately, evictions, soup lines and bread riots passed them by, but the vicissitudes of the Navajo were not simply those of drought and depression. There were other and equally serious problems. For many years the range lands had been heavily overburdened with too many livestock. Disastrous erosion and unbelievable losses of life-giving top soil were the inevitable results. The population had been increasing so rapidly that the density was four times greater than comparable white occupied areas. Poverty was endemic.

The fact that the Navajo people faced environmental and economic destitution does not in itself make the Navajo problem unique. There are many such places in the world. The uniqueness arises from the fact that the Navajo country is a compact geographical unit held in the common ownership of the tribe—an area inhabited by the largest aboriginal cultural minority in the United States.

The Navajos are a distinct cultural group. Racially, linguistically, culturally, they stand apart from all other peoples except the Apaches and a few scattered Athabascan tribes in Northwestern Canada and Alaska. They differ from most other American minority groups in that they have not been in the stream of Euro-American culture.

This complex demanded an advance to a new frontier of thinking. There was a necessity for the application of knowledge, much of which had been theoretical and academic, to urgent and practical problems. There was the basic problem of relating the analyses of the physical and social disciplines. Administration planning and execution of plans had to be synthesized.

The government faced its problem courageously. It was one which might not have become such a festering economic sore had realistic, social and economic planning and administrative action earlier replaced timid paternalism. The government first reorganized its Navajo administrative structure. The six separate administrative jurisdictions that divided the Navajo country were eliminated. This confused and conflicting pattern was replaced by a centralized administrative authority. The many functions of two departments of the government were pooled into the Navajo Service and made directly responsible to the Commissioner of Indian Affairs.

It would be too lengthy here to recount all the steps and missteps, the advances and mistakes, the achievements and disappointments. Every advance in thinking marked an advance in administrative action. There still remains much to be done for the land and the people, but from the present vantage point it is possible to look back and view dispassionately the administrative and conceptual structure that has been built.

Basic to planning and administration in the Navajo country has been the concept of interdependence. There can be

THE TRUE DESERT—ONE OF THE NAVAJO ENVIRONMENTAL REGIONS
ABOUT FIFTY-FIVE PER CENT. OF THE RESERVATION CONSISTS OF DESERT LAND.

no realistic separation of social organization from erosion, poverty or population increase. The intricate web of relationships that bind person to person, whether in the family or in larger social units, manifests itself in the pattern of livestock ownership and range use.

The desperate efforts of a people, with a simple technology, to fill their bellies and clothe themselves and their children may produce a dust bowl. The spiritual values of a people who dignify the heavens and the earth as living beings may place barriers in the way of doing what to us appears reasonable and practical. The values, aptitudes and mechanical habits of the people may hasten or retard conservation and human rehabilitation.

The concept of interdependence is not

THE STEPPE—ONE OF THE NAVAJO ENVIRONMENTAL REGIONS
THE STEPPE REGION INCLUDES HIGH PLAINS, MESAS AND THE LOWER SLOPES OF MOUNTAINS.

THE MOUNTAINS—ANOTHER OF THE NAVAJO ENVIRONMENTAL REGIONS
THIS LAND IS SUITABLE FOR FARMING, SUMMER GRAZING AND FUEL AND LUMBER PRODUCTION.

new to science. The physicists use it, the ecologists and social anthropologists use it in the biological and cultural worlds. Basically, the concepts of these last two disciplines are similar and through them the Navajo Service was able to close the gulf which separates the physical and social sciences. The methodology was that of science. The government used the services of range and livestock technicians, engineers, agronomists, soil technicians, biologists, foresters and social anthropologists. Factual material was sometimes too generalized for planning purposes. It was only when the difference between mere inventories and the information needed for specific planning was realized that lost motion was eliminated.

Basically, the problem of "how" was the meshing of objectives with the values and social organization of the Navajo. Failing that, autocracy was left. The government could have been more authoritarian, but the facts on social organization indicated that the desired objectives could be achieved differently.

From this very generalized view of the problem let us now examine some details of the country and people.

The Navajo reservation with its 16,000,000 acres and 50,000 inhabitants is a portion of the semi-arid Colorado plateau. It is a region of rolling grasslands, shrub-covered valleys, wooded and forested mesas and mountains, cut by deep canyons. Through it all are wide expanses of barren and inaccessible areas. The two factors determining land base, relief and climate, are such that the balance of land stability is uniquely precarious. In such an environment production is limited. It can continuously support a human population only if intensities of land use are carefully controlled and technologies constantly improved.

For the past two hundred years the Navajo has been a sheep man with only supplementary dependence on farming and the sale of his rugs and jewelry, but before the introduction of livestock by the Spaniards and before trading had reached its present high state of development, the Navajos possessed a simpler economy. They farmed, gathered seeds and roots and hunted wild game.

The introduction of livestock permitted and forced seasonal migration of the people. The direction and tempo of this migration and expansion was influenced by the rapid increase of the population and the presence of external pressures. The major external historical factors limiting Navajo expansion was the establishment of the reservation boundaries and the encirclement by white settlers.

Not so many years ago they were able to lessen local pressures by internal adjustments. For many years, as range conditions declined in one area, it was possible for families to take their herds and move to new areas either unoccupied or not as intensively utilized.

Navajo economy is a function of environment. With the simple technology it could not be otherwise. The environment does not permit a great diversity of livelihood activities. Technologies introduced in recent years, as complicated irrigation systems, have broadened the economy. Fundamentally, however, Navajos or any other people must live within the framework of their physical world.

The Navajo country contains three distinctive aboriginal and environmental regions and a fourth, which is man-made. These regions are defined by parallel differences in elevations, temperature, rainfall and the availability of water for irrigation purposes. In each region conditions have given rise to characteristic adaptations in social organization and economy.

The largest region is true desert. It includes about 55 per cent. of the reservation. It is confined generally to the low plains, mesas and valleys below elevations of 6,500 feet. It is the warmest and driest portion of the reservation, with little grass and shrub vegetation and widely scattered watering places. It is the area of predominate dependence upon livestock.

In this desert region the population is sparse and the extended family group is the characteristic social unit. These large family groups are stable aggregates of population. They are interrelated with similar family groups residing in contiguous country. Marriage is frequently polygynous. Authority is definitely crystallized in the male head of the group, who has some of the characteristics of a minor patriarch.

Each group has one or more bands of sheep, cattle and always horses. Daily and seasonal livestock movements are very extensive for purposes of utilizing forage and securing water. Farming, if practiced at all, is on small favorably located places where seasonal floods spill waters over alluvial fans. The deficiency in production of needed vegetable foods is met by selling or trading livestock to traders or other Navajos in exchange for needed commodities.

The steppe is the second environmental area. It covers about 23 per cent. of the reservation. It includes high plains, mesas and the lower slopes of mountains between elevations of 6,500 and 7,500 feet. The climate is more favorable than the desert. The general resistance of steppe lands to erosion is greater than desert and it is capable of supporting larger concentrations of people.

The economy of the people living in the steppe country is a dual dependence on livestock and farming. The sheep are operated in small-sized bands with one band to each family. The movements of people and livestock are seasonal and nearly always circumscribed within limited community areas. Where seasonal movement occurs it is to utilize favorable areas for grazing and wood during winter and for farming purposes during the summer.

Although the relative density of population is greater than in the desert region there is not the same tendency towards clustering of families. One or two but seldom more families live in

THE MAN-MADE NAVAJO ENVIRONMENTAL REGION—IRRIGATED FARM LAND

adjoining hogans. The family groups as mechanisms for cooperative efforts are smaller, but in compensation there is a better-developed community organization.

The principal difference between the third, or mountain region, and the steppe country is in climate and vegetation. It is a relatively small area including about 8 per cent. of the reservation and is restricted to the mountains above elevations of 7,500 feet. The climate is relatively moist and cool. Water is abundant in many permanent streams and springs. The vegetation consists of coniferous forest with oak undergrowth and open parks of grassland. The land is suitable for short-season dry farming, for summer grazing, fuel and lumber production. The economy and social organization varies only in degree from the steppe. Here is found the same dual dependence on agriculture and livestock.

The fourth environmental region is a product of man's technological abilities. In this region the construction of complicated irrigation systems has changed the environment from desert or steppe to an area of fruitful farm lands. It is the area of a characteristic farm economy. The Navajo people who occupy these areas are farmers in every sense of the word. They live on or near their farms the year around. The individual family is the characteristic unit, although for purposes of cooperative farming, groups of families sometimes band together to perform the more difficult tasks. The population is dense and monogamy is the characteristic form of marriage. Acculturation is much more advanced.

Because of the concentration of population and other factors, these man-made environmental regions have become favored places for the location of administrative, educational and hospital facilities.

The critical problem of overpopulation and its attendant evils can be solved for the Navajo people by using the advanced technology of irrigated agriculture.

To meet the ever-growing need for more and more land for this ever-increasing tribe, two great opportunities other than minor projects within the reservation present themselves.

First, the colonization of Navajos on the Colorado River Project, now under construction, is not outside the realm of possibility. Here, 100,000 acres of rich river-bottom lands are being brought under irrigation by virtue of the Colorado River Dam. Part of the justification for the project was the hope that it might be used to resettle landless Navajos. It will not be easy for these people to pull their deep roots from Navajo soil but if economic pressure became great enough and land offers made which are attractive enough, Navajos without land or livestock can, in time, be induced to accept land on the Colorado River.

The second agricultural possibility is the so-called "Turley Project" on the San Juan River. This, or a similar development on the San Juan, would make use of New Mexico's water quota under the Colorado River Compact and would place approximately 40,000 acres of Indian land under irrigation. This would be a tremendously expensive project, estimated to involve an expenditure of over $50,000,000. It probably is not justifiable for commercial agriculture, but it can be justified for subsistence farming. This project would irrigate a larger area of White lands than Indian.

Navajo technology and environment exhibit a fundamental interdependence. Environmental regions have effected the way in which Navajos relate themselves to each other; but environment does not rigorously dictate the customs or groupings of a people. Among all Navajos there is a basic cultural similarity, irrespective of the economy or environment. An understanding of these sociological

NAVAJO FAMILY GROUP AT THE HOGAN OF FRANK CATRON
NEAR TOHATCHI, NEW MEXICO. NOT INFREQUENTLY LARGE FAMILY GROUPS LIVE IN ONE HOGAN.

NAVAJO GIRLS CARDING AND SPINNING WOOL FOR WEAVING

similarities is basic to an understanding of the total problem.

The study of Navajo social organization reveals that there are three major social groupings, each of which varies in size, characteristics and functions. Each social grouping has its own characteristic structure and leadership. Each group is capable of filling specific needs and meeting the constantly recurring greater or lesser crises of life. The daily, seasonal or yearly events are faced not by independent individuals, but by persons who carry a common language and similar customs, and who have established habitual patterns of accomplishment and working together for mutual benefit. Each social grouping has its own emphasis in the environment in which it is found.

Basic to all Navajo social organization is the family. The Navajo family is that social unit which comprises all those persons living within one hogan. It may include but two persons, a woman and her husband, although the characteristic family group includes children and in some instances grandparents or even other relatives.

The organization of activity by which the family fills its needs is reflected in the division of labor on the basis of status, sex and age. The father and husband is the nominal head. The woman's role as mother and wife is limited compared to that of her husband. The hogan and its vicinity represents her locale of action. She is responsible for the preparation, serving and cooking of food; for the cleanliness of the hogan and her children; for making the clothing and for the general comfort of members of her family. She is the weaver and seller of rugs and her economic contribution to the family can not be overemphasized, but she is equally competent in the care of the sheep and assists her husband in the light work in the fields when the necessity arises.

FOUR NAVAJOS PROUDLY DISPLAY THEIR SHEEP

BETTER MANAGEMENT METHODS HAVE INCREASED THE PRODUCTION AND QUALITY OF NAVAJO WOOL.

The Navajo family can be viewed as an interdependent group of persons residing in one hogan, meeting the immediate and daily needs of its component members. Adequate as this social unity is for most purposes, there are many activities and crises which are not met by the individual family but by groups of families in cooperative effort.

The creation of a new family unit by the marriage of two individuals is, in Navajo thinking, not the union of two separate individuals but the establishment of a relationship between two families. The negotiations, the exchange

of property, the religious and secular aspects of the marriage and the residence of the newly married pair emphasizes this fact.

Those ties which bind family to family by reason of either blood or marriage are rarely completely severed. These ties manifest themselves in many ways. The construction of a new hogan or corral; the shearing or dipping of the sheep, all calls forth the cooperative labor of the family group.

The family group then represents a group of families possessing common close ties by blood or marriage, resident in one locality under one leadership and manifesting structure in the cooperative sharing and common meeting of crises of a greater intensity than those facing the family.

The family and family group are common features of Navajo social organization, easily recognized and described. Less well-known and more difficult to observe, because its manifestations are less apparent, is what we may correctly designate the land use community.

This social and economic unit usually contains a number of family groups living in a contiguous area. The external limits of the area of use form the boundary separating the community from other land use communities which are comparable in function and internal structure. Historically these communities and their area of use have each remained relatively stable. Each land-use community can be identified with a specific area of country. The occupants lay claim to the country as their own on the basis of ancestral settlement and present use. It is because of the territorial and use characteristics that this social group has been called the land-use community. Cooperative community labor and leadership exhibits itself most often in general problems relating to range use and water, the development

A NAVAJO TRIBAL SAWMILL ON THE EDGE OF A LOG POND

ROUND-UP OF CULL HORSES FOR SALE AND REMOVAL FROM THE RANGE

OTHER RESERVATION HORSES WILL BE BETTER-FED AFTER HORSES LIKE THESE ARE REMOVED.

of farm land and the presentation of a united front toward those who attempt to encroach upon the community rights.

The land use community as a mechanism for planning and administration has important implications. Through the recognition of community areas of the people residing in the community and of their activities, it is possible to indicate specific areas for administration planning. The same mechanisms of cohesion and direction operating within a community group will continue to operate where administration recognizes and manages land on a community basis.

Another factor which had a great influence on Navajo economy must be mentioned briefly: the institution of trading. Traders to the Navajo fill a unique place in Navajo economy. They buy nearly all the things the Navajos sell. They sell nearly all the things the Navajos buy. The trader is the arbiter of Navajo fashions. He creates new wants and desires. Through his system of credit and exchange he exerts an enormous influence on Navajo life. If he is an efficient and devoted humanist as well as a merchant, he is a force for great good, but if through indifference to the welfare of the people with whom he trades he descends to the level of mere profit-making he can impoverish whole communities. The trader has undoubtedly made his contribution to the Navajo problem.

A government with superficial attitudes toward its Indian charges and a blind devotion to soil conservation might have passed off the Navajo crisis as a simple one of erosion caused by too many sheep, cattle and horses. It might have accepted the reduction of livestock as a cure-all. In reality the problem was and is much more complex. Fundamentally, it was caused by the attempts of too many people confined to a limited area, schooled in the tradition of a one-crop livestock economy, to wrest a living from unfertile lands. It was caused by ever-increasing commercial wants that could be met only by producing more and more livestock. It was caused by a costly and inefficient system of distribut-

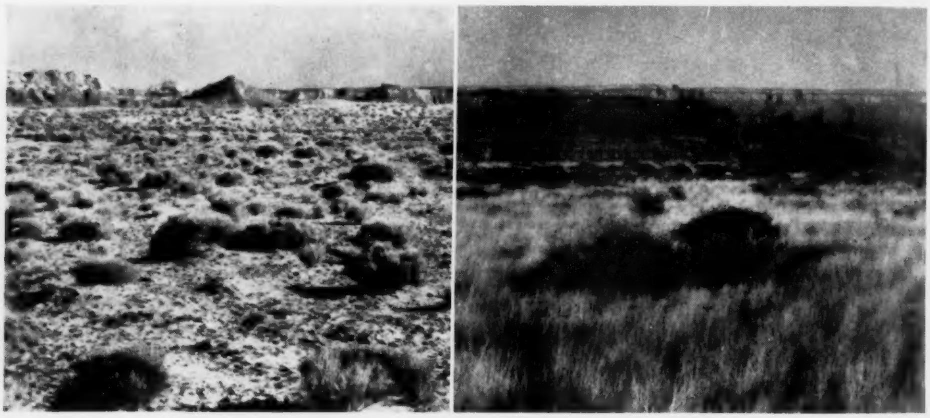
ing consumer goods. It was caused by an inability to understand and apply more advanced technologies. It was exaggerated to some extent by the blindness of government. These and many other causative factors reached a climax of severity in the drought of the 1930's.

There is general agreement as to the events that developed in the Navajo crisis. A clear-cut analysis has made possible a clear definition of the broad objectives. They are:

(1) Establishment of universal proper land use.
(2) Development of irrigated farmlands.
(3) Redistribution of the population for efficient utilization of resources.
(4) Strengthening the economic position of Navajos by means of extensive tribal and cooperative enterprises.
(5) Preservation of cultural integrity.

These objectives were formulated in a statement of policy on planning and administration, which follows:

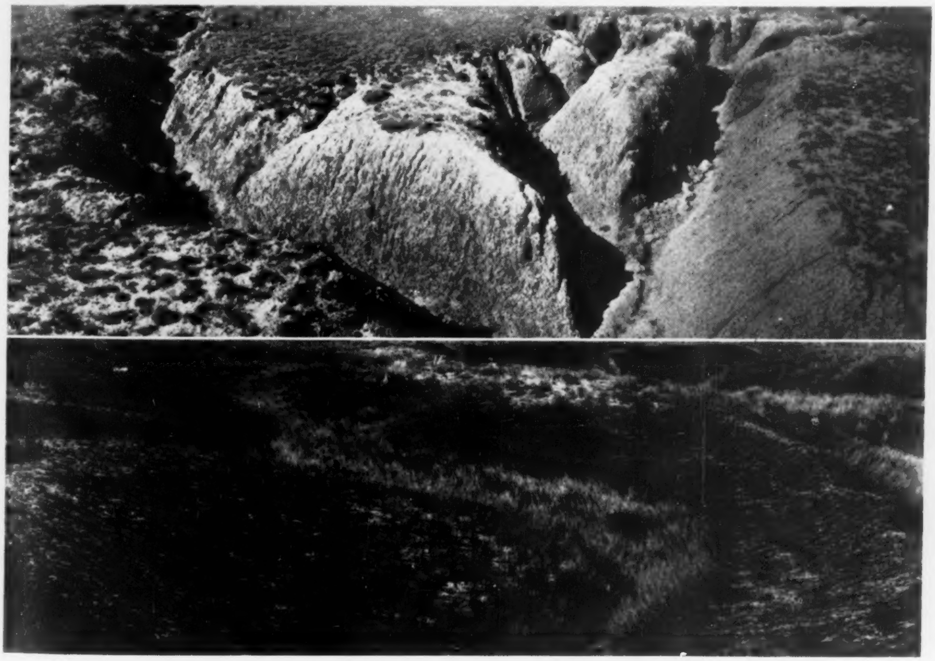
(1) That the responsibility of the government is twofold:
 a. Conservation of natural resources.
 b. Improvement of human life.
 And that these two functions are complementary and interrelated.
(2) That the fundamental responsibility for land use, in a democracy, rests with the people who use the land and that though in the present case this responsibility is compromised by the trusteeship of the government and hence must conform to its policies, the ultimate goal shall be the furtherance of Navajo participation and responsibility in the management of their resources.
(3) That planning, here defined as the organization of knowledge for action, must be realistic in terms of the setting in which the action takes place. That realism connotes that life is lived dynamically within a functionally integrated set of relationships and on land. Fact-gathering and analysis may proceed piecemeal; overall planning to be intelligent, or what is more important, to be intelligible, must be done whole.
(4) That the Navajo area by reason of certain cultural and administrative consideration is a regional unit for planning, but that the problems therein considered have extra-area implications and that within the area local variations require special consideration. Treatment is regional within the definition of the word as a comprehensive and composite picture of man-land and man-man relationships in a defined area of use.
(5) That overall planning, though it must function at a highly generalized level, must avoid generalities and must be specific with regard to problems and conditions, the people they affect and the methods of treatment.
(6) That no plan can be final to the end of time or specific to the smallest detail. Flexibility and modifiability due to local conditions and changing times are essential to the effective utilization of plans.
(7) That day-to-day administration and direction of Indian affairs is the means by which



PICTURES "BEFORE" AND "AFTER" REVEGETATION
RANGE MANAGEMENT HAS PLANTS GROWING IN MANY AREAS FORMERLY BARREN OF GRASS.

FLOCKS OF SHEEP ON THE NAVAJO RANGE AT SUNSET

OVERSTOCKING ON THE RESERVATION HAS BEEN REMEDIED LARGELY BY THE SALE OF CULL ANIMALS.



EROSION CONTROL THROUGH RANGE MANAGEMENT

VEGETATION PREVENTS SHEET AND WIND EROSION SUCH AS THAT SHOWN IN THE TOP SECTION.

overall and long-time objectives are realized, that day-to-day needs of people must be met without losing sight of major purposes.

The past eight years have not been easy. There has been misunderstanding and opposition. There has been blundering. Popular writers have frequently misinterpreted the facts to the public. The wonder is not that there has been strife but that it has not been more severe. The situation demanded a revolutionary change in the technology and economy of an unsophisticated people. The Navajo have come through this crisis a stronger and more intelligent people.

There are many phenomena that can be expressed in quantitative terms. Much of the resurgent and revitalized Navajo behavior can not be thus expressed. The intense interest in improved livestock husbandry; the spreading interest in cooperatively owned trading posts; the farm, livestock and other associations; the responsible and recently developed optimistic tenor of meeting with leaders, are but manifestations of the strengthening of the Navajo's belief in his ability to cope successfully with the future.

Significant, concrete forward steps have been made in all the major phases of land use. Plant cover is almost universally improved. Areas formerly barren of grass cover are now in various stages of recovery with plant succession moving definitely in advanced climatic stages. Although gully erosion and silt production are still high, sheet and wind erosion have been measurably reduced.

The range livestock industry has been placed on a firm foundation by a reduction of livestock numbers to carrying capacity, and livestock improvement has been correlated with the reduction in such a manner that increased income has more than kept pace with reduction in numbers.

The percentage of overstocking on the reservation as a whole has been brought down progressively from 100 per cent. in 1932 to 34 per cent. in 1937, and to less than 1 per cent. in 1941. All this reduction since 1935 has been achieved by the sale of cull animals and the removal of powerful Navajo commercial operators to range lands outside the reservation.

The rapid expansion and successful settlement of farm land has given many Navajos security where before their existence and dependence on submarginal livestock or farming was precarious.

There has been a great expansion of cooperative enterprises. For many the tribe has used its own monies. These enterprises include an important lumbering industry; tribal flour mill; cannery; nursery, and farming enterprises, together with an important tribal project to buy and process cull animals for removal from the range, as well as a tribal project of considerable importance for the purchasing and distribution to the poorer people highly improved rams. A fund is now available for Navajo arts and crafts; to increase the production of salable handicraft, and for finding new and heretofore unreached markets. Navajo-owned cooperative trading posts are now in operation. Others are now in the process of organization. These Navajo-owned stores are operated on a non-profit basis. In their locality they are becoming the center of all community activities.

Navajo leaders are assuming objective progressive attitudes towards the many problems still facing the people and the government. They are accepting as never before the criticisms, burdens and responsibilities that must be the lot of any true and strong leadership.

On the basis of present plans and procedures we may visualize the future of the country and people of the Navajo. It can never be a land of milk and honey. The rigorous environment holds a never-

INTERIOR OF MEXICAN SPRINGS COMMUNITY TRADING ASSOCIATION
COOPERATIVE TRADING TAKES PLACE AT THIS POST IN MEXICAN SPRINGS, NEW MEXICO.

LOOKING TOWARD THE NAVAJO TRIBAL COUNCIL HOUSE
AT THE NAVAJO CENTRAL AGENCY, WINDOW ROCK, ARIZONA, WHICH WAS ESTABLISHED IN 1935.

INTERIOR OF THE NAVAJO TRIBAL CANNERY AT MANYFARMS, ARIZONA

ending challenge to man. But we know that the range is healthier than for many years. The livestock industry is fast approaching a level of high efficiency. Most young people must now turn to newly developed irrigated land for their livelihood. The land-use community will continue to be a responsible planning and administrative unit.

The future which most Navajos ardently wish for themselves and their children is the status of responsible, self-respecting, self-supporting citizens. Many minority peoples have been shattered by a too violent contact with an aggressive foreign people. The Navajos are not likely to suffer that unfortunate fate since the economic basis of cultural expression has been used by the government to strengthen the whole people.

The Navajos have learned in a decade a vast amount of the technological knowledge that Euro-American culture required centuries to build. They still do not understand the reason for many things they do, but find the results convincing.

The barriers of technological differences are being gradually removed. The Navajo farmer and stockman and his white neighbor are going through a common experience and from that comes common understanding.

The pattern of Navajo administration and planning is applicable to problem peoples wherever they may be. Through organization, direction and purpose the separate scientific disciplines have been integrated and findings converted to the level of action. A framework of administration and planning in full recognition of the total problem has been developed. The most complicated problems have been met through recognition of the many facets of a dynamic situation.

The need of total planning for other areas of the world is all too apparent if our democratic forms are to survive.

SOME GEOGRAPHIC ASPECTS OF LIMNOLOGY

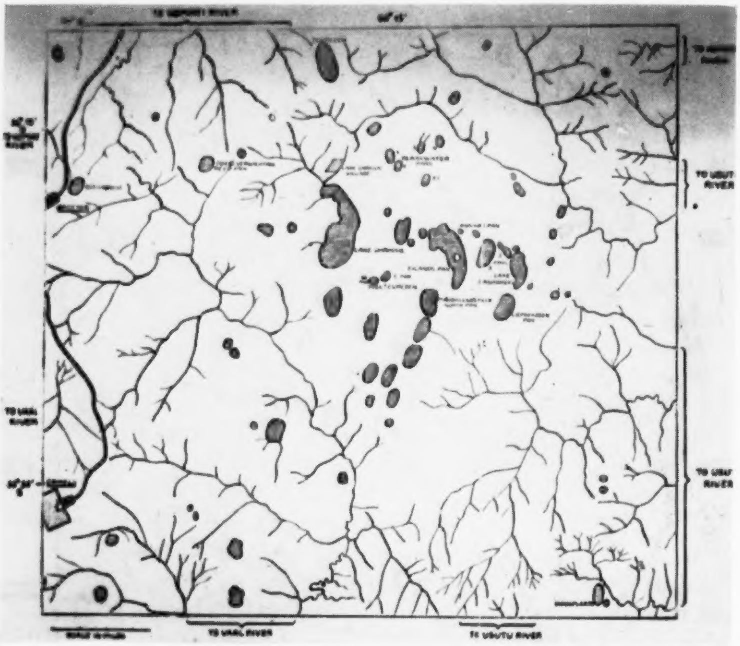
By Dr. EDWARD S. DEEVEY, JR.
DEPARTMENT OF BIOLOGY, THE RICE INSTITUTE

THE lakes of the world do not bulk large on the map of the world or even on the maps of the continents. In some regions, of course, lakes dominate the landscape; yet in one of these places, Vilas County, Wisconsin, only about 15 per cent. of the area is under water, although the proportion in some parts of Finland and Minnesota is probably a little larger. South of the limits formerly reached by the great continental ice sheets lakes are very scarce and, aside from those formed by man, they may be almost wholly lacking in many states, such as Virginia and the Carolinas.

One must not judge the geographic importance of a feature by its areal extent, however. Gold mines and good harbors are even scarcer than lakes. I know of no lake comparable to a gold mine, unless some of the lakes of petroleum in California may be admitted to the comparison. I wish merely to draw attention to the fact that limnology, the study of lakes, is a geographic science. "To them that have shall be given," and to the modern geographers, who already have cast irredentist glances at geology, meteorology, oceanography, economics, anthropology and a host of other subjects, I make a present of still another "ology."

The question of the origin of lake basins is one of some geographic interest; the ecologist must also concern himself with the matter, since the origin usually determines the shape of the lake, and thus the hydrographic conditions and the nature of the biota. The biological history and to some extent the chemistry of the lake may also be bound up with its method of formation. The principal methods may be listed as follows:

FIG. 1. SALT FLAT, AN EXTENSIVE PLAYA IN THE SALT BASIN
HUDSPETH COUNTY, TEXAS. THE BASIN IS A FAULT VALLEY, OR GRABEN, THE WESTERN SCARP (DIABLO PLATEAU) IS VISIBLE IN THE DISTANCE.



Archiv für Hydrobiologie

FIG. 2. MAP OF THE LAKE CHRISSIE DISTRICT, TRANSVAAL

SHOWING NUMEROUS SUBCIRCULAR PANS SCOOPED BY THE WIND IN AN ARID CLIMATE. DUE TO AN INCREASE IN RAINFALL THE PANS ARE NOW TEMPORARY OR PERMANENT LAKES.

1. Faulting and other structural changes
2. Wind action
   a. Deflation basins
   b. Lakes between dunes
3. Glacial action
   a. Dams formed by glaciers or their moraines
   b. Excavation by ice (cirques and troughs)
   c. Melting of blocks of ice embedded in outwash (kettles)
4. Fluviatile action
   a. Dams formed by levees
   b. Ox-bows
5. Solution
   a. Limestone sinks
   b. Depressions formed by solution of subterranean salt deposits
6. Volcanic action
   a. Caldera lakes
   b. Dams formed by lava flows
7. Organisms
   a. Basins eroded by ungulates (buffalo wallows)
   b. Basins dammed by beavers
8. Landslides
9. Meteorites

By way of summary of the geography of lake basins, one may notice, first, that lakes are generally by-products of processes resulting in physiographically youthful landscapes, and second, that lake-forming processes tend to be geographically restricted, so that we have "lake districts," characterized by lakes of one or two types.

If the existence of lakes is subject to geographic influences, their characteristics are equally so. The most important of these influences may be grouped under two headings, climate and lithology. Relatively little is known about the climatic factor in limnology; most of the world's limnologists live in the humid temperate regions of North America and western Europe, and those who have ventured out of this supposedly "ideal" climate into the tropics, high mountains, the Arctic or deserts, have been hampered by lack of equipment, adequate laboratory facilities and time. Most of our information about tropical lakes comes from the work

of the German Sunda Islands Expedition, and of Worthington and his colleagues on the Cambridge Expedition to the East African Lakes; for mountains we have the studies of Steinböck, Pesta and Leutelt-Kipke in the Alps, Hutchinson in the Himalayas, and very recently Pennak in the Colorado Rockies; desert lakes have been chiefly explored by Gauthier in the Sahara and by Hutchinson in South Africa and Nevada; no serious limnology has ever been done in the Arctic or Antarctic.

I shall not attempt to discuss the influence of the temperature element of climate on lakes of different latitudes and altitudes; to do so would lead us too far into physical questions for the purposes of this paper. The rainfall element requires some attention, particularly as the expression "desert lake" sounds like a contradiction in terms to the average person. A true desert, of course, contains neither rivers nor lakes, but true deserts are comparatively rare. Most of the countries popularly called "deserts" are regions of *interior drainage*, in which more or less permanent rivers flow into more or less permanent lakes, but do not reach the sea.

As the lakes of these regions usually lack outlets, they act as gigantic evaporating pans, accumulating the salts delivered by rivers and ground water. Yet in spite of a relatively long time of accumulation, the concentration of electrolytes seldom approaches saturation. This is evidently because the arid lake districts are transitional, both geographically and climatically, between true deserts and moister regions. In dry periods the lakes dry up and their deposited salt blows away; in moister periods outlets form and the salts are washed out of the lakes to the sea. This susceptibility to slight climatic changes adds much charm and much exasperation to the study of desert lakes. Even the best maps tend to be unreliable, and mirages add extra zest to the life of the limnologist, who may not have suspected before his first trip to a desert that even slightly moist clay can reflect the surrounding mountains.

As a result of excessive concentration of electrolytes the lakes of arid regions

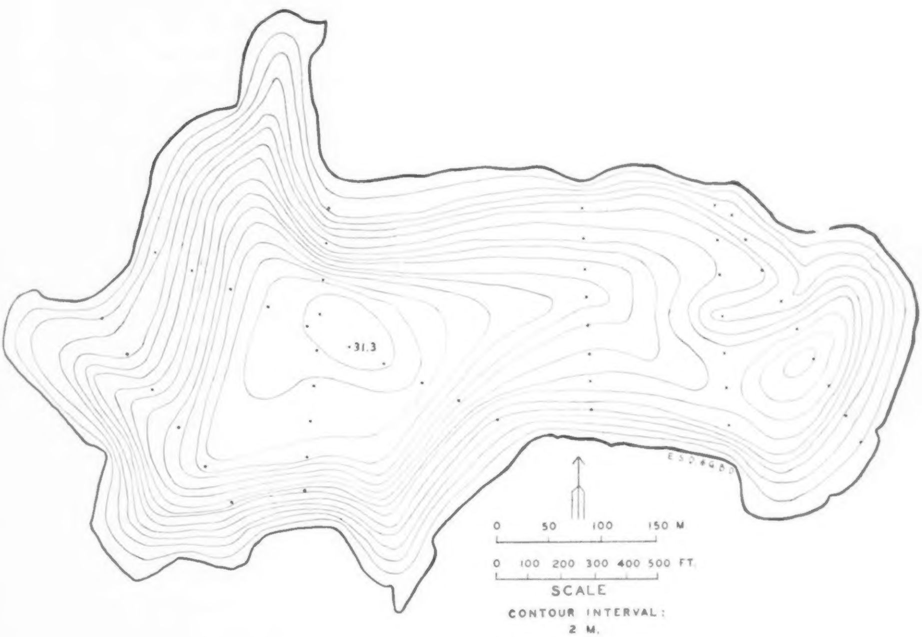
FIG. 3. ICEBERG LAKE
A CIRQUE LAKE NEAR MANY GLACIER, GLACIER NATIONAL PARK, MONTANA.

have a very select fauna and flora, consisting in extreme cases of one species of animal, the most familiar being the brine shrimp, Artemia. Often animals are absent, and the plankton is composed of plants alone. But as phosphorus tends to accumulate along with the other minerals, such lakes are very fertile, and the biota is usually rich in individuals.

Aside from the elements of climate, another group of geographic factors determines the character of lakes. This is the group collectively known as lithologic. We can see the operation of lithology more clearly in humid temperate regions, where climate can be assumed to be relatively uniform over wide areas. One lake may be rich in black bass because it has stony shores and lots of crayfish, another may be rich in crappie because it has shallow mud bottoms with weed beds abounding in insect life, and a third may support lake trout and salmon because there is a large reservoir of cold, well-oxygenated water in the depths into which those species can retreat in summer. But of course animals do not create food; they merely transform it, and in the final analysis the total quantity of life that a lake can contain depends on the chlorophyll-bearing members of the plant kingdom, which synthesize organic matter from inorganic materials, using the energy of sunlight. These plants in turn are dependent on certain inorganic substances. There is always plenty of water about in a lake, and there is usually plenty of carbon dioxide; but most of the elements of the periodic table are essential to the proper growth of some organism or other, and it will be obvious that the element which is present in smallest amount in nature in proportion to the needs of organisms will become a limiting factor or bottleneck. This element in the great majority of cases is phosphorus. Nitrogen may also act as a limiting factor, but of course the air is four fifths nitrogen, and provided certain bacteria are present either in

Ecological Monographs

FIG. 4. LINSLEY POND, NORTH BRANFORD, CONN., A TYPICAL KETTLE.



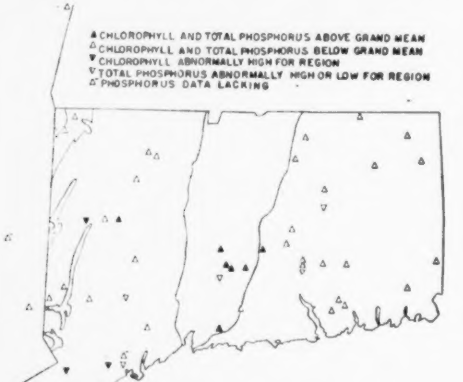
Quarterly Review of Biology

FIG. 5. BATHYMETRIC MAP OF WALDEN POND, CONCORD, MASSACHUSETTS SHOWING THE STEEP BANKS CHARACTERISTIC OF KETTLES.

the lake or in the surrounding soil, the atmospheric nitrogen can be transformed into a form which can be used by plants.

As a result of the knowledge of limiting factors in plant growth, when we find that lakes of one area are rich in all forms of life, from microscopic free-floating algae or phytoplankton, up through small animals (zooplankton) that graze on the algae to fish and other large animals that eat the small ones, while the lakes of another area are poor in all departments, we need not blame the fisherman or a mild Labor Day week-end or the niggardly stocking policy of the State Fish and Game Department. Nor, as ecologists seeking limiting factors, do we need to examine the whole periodic table for the explanation; we immediately suspect phosphorus. Some rocks are high in this element, others are low, and just as this unequal distribution is reflected in the fertility of the agricultural soils derived from the rocks, the productivity of lakes is governed by the lithologic factor. At any rate, this appears to be the reason why northern Germany and the region around Madison, Wisconsin, are very fertile lake districts, while northwestern Wisconsin, the highlands of Connecticut and parts of Japan are not. Even within the borders of a state as small as Connecticut we can see this factor operating, for there is a low-lying belt of soluble sedimentary rocks cutting across the highlands, which are composed of gneisses and schists and are probably poor in phosphorus. In the lowland lakes the phosphorus content of the water *and* the quantity of phytoplankton are above average, while in the highland lakes the phosphorus and plankton are below average, with some minor exceptions (Fig. 6).

So far we have been considering, from a rather special point of view, the lakes



American Journal of Science

FIG. 6. PHOSPHORUS CHLOROPHYLL DISTRIBUTION IN FORTY-NINE CONNECTICUT AND NEW YORK LAKES. THE IRREGULAR NORTH-SOUTH LINES ENCLOSE THE CENTRAL LOWLAND OF SEDIMENTARY AND IGNEOUS ROCKS. THE HIGHLANDS ARE COMPOSED OF METAMORPHIC ROCKS, EXCEPT IN THE DOTTED AREAS, WHICH ARE COMPOSED OF STOCKBRIDGE MARBLE.

of the world as we see them to-day. But no geographer can afford to forget that the present-day face of the earth is, as it were, a single frame in a continuous moving picture film. Physiography is constantly evolving under the impetus of forces set in motion long ago, the wearing down of continents and the filling up of basins, the shearings and crackings of the earth's restless crust, and the climatic conditions brought into being by the effect of land and sea on the circulation of the atmosphere. The form and characteristics of lakes, indeed their very existence, are naturally subject to the same forces, and the limnologist must reckon with changes that have taken place in the recent and sometimes in the more distant past. In fact, it is in this field of historical limnology that the biologist can contribute most effectively to the broad science of geography.

The last important epoch in the earth's history, and therefore the one about which we have the most information, was the Pleistocene (meaning "most recent") or Ice Age. The whole span of this epoch was probably not more than a million years, a relatively short section of the recorded age of the earth. During this time, as every one knows, great ice sheets formed at high latitudes and crept down the continents to latitudes as low as 40° in the northern hemisphere; several such advances, separated by partial or nearly complete retreats, are known to have taken place, and at approximately the same time local glaciers formed on high mountains, even within the equatorial zone, and sent arms of ice down the valleys into the plains below. But the startling climatic and physiographic changes wrought during the Pleistocene were not confined to the regions actually chilled or eroded by ice. Not only did the oceans rise and fall as more and less of the earth's supply of water was alternately imprisoned and released by the ice masses; in most parts of the world the climate was appreciably moister during periods of glacial advance and drier during interglacial ages. The effects of these climatic changes are especially well seen around many of the lakes of unglaciated regions, where high beaches and shore-line features record lake levels much higher than those of to-day. The Great Salt Lake, for example, large as it is, is a mere shadow of its former self, Lake Bonneville, which filled a number of now-dry basins to a maximum depth of more than a thousand feet, and had an outlet to the north. Another large lake, Lake Lahontan, occupied several adjacent basins of western Nevada, but as the climate became drier it shrank to a few saline pools such as Pyramid and Winnemucca Lakes, of which at least one is still extensive enough to attract tourists from Reno with time on their hands. The periods of unusual moisture that permitted these great lakes to exist are called "pluvial periods," and there appear to have been at least two of them during the Pleistocene, corresponding roughly to the first

two and the second two glacial ages of cooler countries, and separated by an interpluvial, which in some places was one of intense aridity.

The detailed study of any of the great pluvial lakes is extremely fascinating, but I shall discuss only those of equatorial Africa, no longer called "darkest" except in Hollywood, for its dramatic Pleistocene history is the best known of any comparable area (Fig. 7). This history is made rather complicated by earth movements which occurred on a gigantic scale, and many details remain to be filled in; in particular the dates of many events are still uncertain, but fortunately, as the evolution of the topography of this region is intimately bound up with human prehistory, geographers and biologists have been able to enlist the very valuable services of the archeologists, who have corroborated many inferences and added much new information of their own.

During most of Cenozoic time the center of Africa was like an immense flat-topped dome. On this dome the principal river systems rose in a huge swampy area, through which their headwaters intercommunicated, and flowed radially to the sea. The fishes of all the river systems and their associated lakes thus had an opportunity to mingle, and even to-day we find that the genera of the Nile, Zambesi, Congo, etc., are the same for the most part, although the species are different. The rivers of Uganda flowed westward to the Congo. Toward the close of the Cenozoic, however, earth movements began to be felt; the first great change appears to have been the gradual sinking of part of the central dome to form the basin of Lake Victoria. This process resulted in the reversal of the Uganda rivers, which were then decanted into Lake Victoria. As the movements of the crust were intensified, immense faults were formed, and the great Rift Valleys were dropped down between the faults, the western Rift coming to lie athwart the Uganda rivers. This caused their western sections to be diverted again, but now the harassed water flowed into the Rift and made its way northward to the Nile. Intercommunicating lakes occupied the deeper portions of the Rift Valleys, and as the first pluvial period occurred about this time, these lakes were much deeper than to-day.

The connection of the Rift Valley lakes and Lake Victoria with the Nile drainage gave opportunity for aquatic animals to make their way from the Nile into the lakes, there to evolve into new species adjusted to different conditions but showing strong affinities with their Nile ancestors. But during the great interpluvial the climate was so arid that all the lakes, with the exception of Tanganyika and Nyasa, whose bottoms are below sea level, dried up, and the aquatic fauna was extinguished. A whole new colonization from the Nile took place during the second pluvial period, when

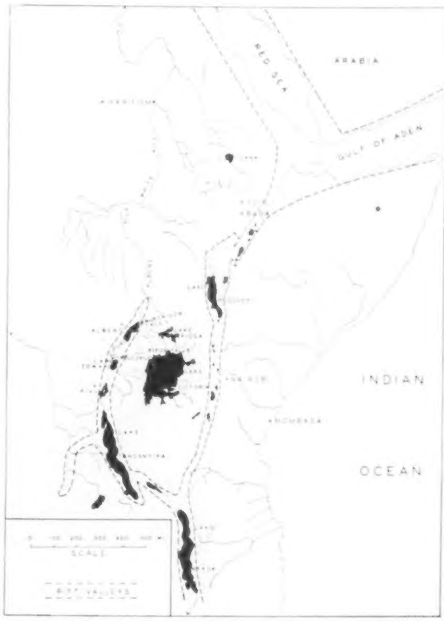


FIG. 7. EAST AND CENTRAL AFRICA SHOWING THE RIFT VALLEYS (ENCLOSED BY DASHED LINES).

the lakes reformed, and the species of the modern lakes still show affinities with those of the lower Nile. However, many interesting details have prevented a complete mixture and uniformity of species. For example, the Nile crocodile is now absent from Lake Edward, apparently because it has been unwilling to walk around the Semliki Falls through several miles of dense forest in order "to see what there is on the other side," as Worthington puts it; it is known to have been present during one of the pluvial periods, but was wiped out when Lake Edward dried up. As the crocodile has managed to get around the Ripon Falls into Lake Victoria, this lack of initiative seems surprising. To take another example, the fauna of Lake Rudolph is very like that of the Nile, although Rudolph is now quite saline and without outlet. An outlet to the Nile almost certainly existed during pluvial times, however, when the lake was about 475 feet deeper than to-day, and spilled out of the Rift Valley through a gorge.

Other differences in detail occur which are really striking, and they evidently stem from the fact that the colonization of the lakes was to a considerable extent accidental, depending on the species which happen to have got around such barriers as the Semliki, Murchison and Ripon Falls, and their subsequent evolution into new species. Thus of 111 species of fish found in Lake Victoria, 85 are endemic, that is, found nowhere else in the world, while in Lake Edward, 22 of the 38 species are endemic. The molluscs also show a high degree of endemism in the lakes.

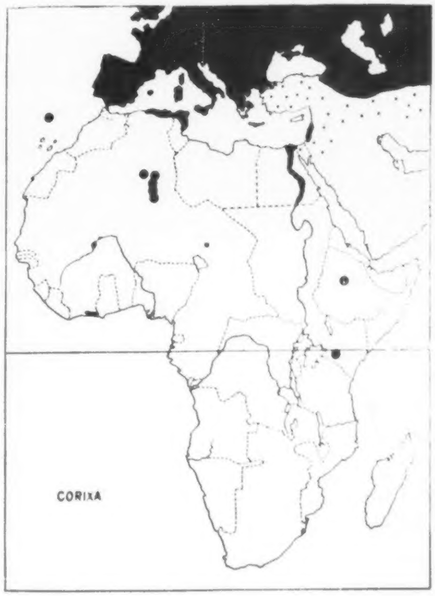
From the biological standpoint the most remarkable of the African lakes are Tanganyika and Nyasa, which alone are deep enough to have contained water continuously since before the Ice Age. They are true aquatic "lost worlds," with an exceedingly high proportion of their species restricted to them. In Tanganyika, which is much the better known of the two, in addition to the fish, of which 131 species, or 79 per cent., are endemic, there is a vast array of novelties, such as a group of spiny molluscs curiously resembling marine forms extinct since the Jurassic; this resemblance is now known to be superficial, and while the fauna of Tanganyika is old, it is not a survival from the Mesozoic. There are endemic species and even genera, among the insects, crustacea and several other invertebrate groups, and the fauna includes a remarkable fresh-water jellyfish, which, however, has recently been found elsewhere in Africa.

Parenthetically, I may remark that there are at least two other lakes comparable to Tanganyika in that they have led a continuous and rather isolated existence since the Tertiary, and in the exuberant evolution of peculiar species in their waters. The more extraordinary is Lake Baikal, in Siberia, and the other is Lake Ochrid, in the Balkans. Probably 90 per cent. of the animals of Baikal are found nowhere else, and a large proportion belong to genera which are also unique.

The effects of the pluvial periods were naturally not confined to equatorial Africa. Lakes expanded in the Sahara as well as in South Africa. In the Sahara several of the oases, such as Kharga and the Faiyum depression, held lakes during pluvial times, and as primitive man lived on their shores and on their dry bottoms when opportunity offered, archeology has been able to provide datings for the geologic events. One of the most interesting by-products of a moister Sahara was the leakage of European species of aquatic animals into equatorial Africa, as shown for example by the geographic distribution of several species of Corixa (Fig. 8), the water bugs known as "water boatmen."

A species whose present distribution

can not be accounted for by present conditions, but is clearly the product of conditions obtaining in the past, is called a "relict"; we speak of *Corixa mirandella* as a "pluvial relict," but other types of relict distribution are known. On the northern continents many species, both aquatic and terrestrial, show a distribution that is obviously related to glacial ages rather than to present climatic conditions, and these are "glacial relicts." In fact, there is good reason to believe that important readjustments are taking place in the ranges of animal and plant species all over the world to-day, simply because the time elapsed since glacial and pluvial ages has been too short for the attainment of equilibrium. The subject is one of immense geologic and geographic importance, but progress has been hampered by excessive departmentation; not only have geologists been ignorant of the work of students of animal and plant distribution, and *vice versa*, but authorities on the distribution of one animal group, say the beetles, have paid no attention to the work of experts on other groups, say the tree-frogs or the water-fleas.



Internationale Revue der gesamten Hydrobiologie und Hydrographie

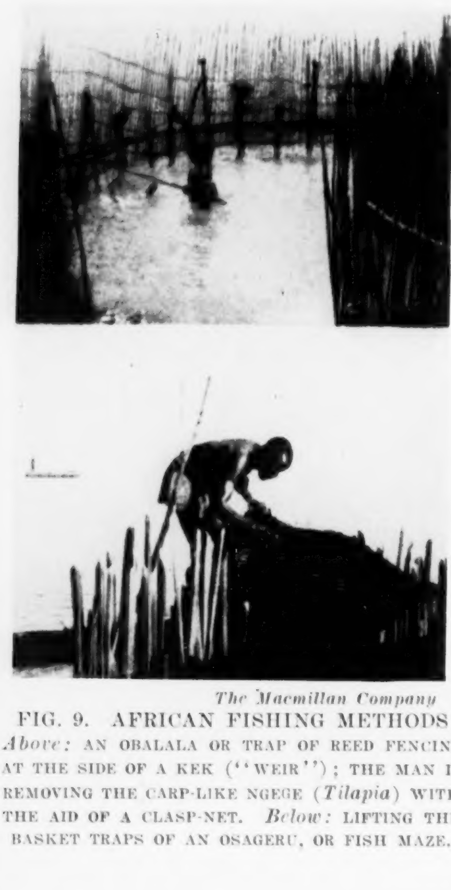
FIG. 8. WATER-BUG DISTRIBUTION

GENUS CORIXA IN AFRICA AND EUROPE. DURING THE PLUVIAL PERIODS A MOISTER SAHARA EVIDENTLY ALLOWED SEVERAL SPECIES OF THIS GENUS TO "LEAK THROUGH."

Before concluding this survey of geographic limnology, I should like to consider some of the relations between limnology and human geography—some of the ways in which lakes as geographic units affect the distribution and culture of man. These relations are especially close and conspicuous in the case of primitive man. To be sure, important instances can be found in which lakes affect the welfare of the human race in its most "civilized" state; we hear much of the military strategy centering about Lake Ilmen and Lake Ladoga, and of Russia's Caspian Sea lifeline, and in densely populated countries like Central Europe and China, the annual fish crop of inland lakes is managed and harvested with scrupulous care, aquaculture being nearly as important as agriculture. To a smaller extent this is true of our own Great Lakes area. Admiral Horthy's title is not one of courtesy; the Hungarian Navy sails the shallow but extensive waters of Lake Balaton. And according to recent news reports a U. S. Navy hydroplane contrived to set itself down on a mirage in southern Texas. But these instances are bound to be exceptional if only because of the relatively small fraction of the earth's surface occupied by lakes. In many areas where lakes are most abundant, such as Wisconsin and Maine, their chief modern use is for recreation, in pursuit of which civilized man temporarily returns to the economic activities of his primitive ancestors, hunting and fishing.

The integral part played by lakes in the culture of primitive peoples is nowhere better illustrated than in the lake district of equatorial Africa. The shores of Lake Victoria and the other lakes

support numerous fishing villages, the people of which may have little in common except that they are black and adopt fishing as their chief means of livelihood. The type of boat constructed and the methods used to capture fish differ widely among the various tribes, depending partly on local conditions and available species of fish, but mostly on the independent evolution of methods by people of different racial stocks having relatively little contact with each other. Most of the methods used are highly ingenious and have not been improved upon by civilized man; they include seines, weirs, hand baskets, traps, hand lines, set lines, angling and a host of minor variants (Fig. 9). All of them



The Macmillan Company

FIG. 9. AFRICAN FISHING METHODS

Above: AN OBALALA OR TRAP OF REED FENCING AT THE SIDE OF A KEK ("WEIR"); THE MAN IS REMOVING THE CARP-LIKE NGEGE (*Tilapia*) WITH THE AID OF A CLASP-NET. *Below:* LIFTING THE BASKET TRAPS OF AN OSAGERU, OR FISH MAZE.

imply close study of the habits of the different species, and in fact it is axiomatic that primitive hunters and fishermen are very able naturalists. One of the most extraordinary methods of capture employed on Lake Albert makes use of the natural food chains of the lake, a phenomenon which did not receive adequate scientific attention until a few years ago (Fig. 10). The natives lower bundles of brush in about 30 feet of water, marking them with buoys. Each morning they haul them up, and extract the many tiny fish (Haplochromis) which worm their way in, seeking shelter. The Haplochromis are fixed to a hook and dangled overside on a pole, where they serve as bait for their natural enemy, the voracious tiger fish, a pickerel-like fish over a foot long. When caught, the tiger fish are then fixed to an enormous iron hook attached to a long rope. They are the bait for the real quarry, the gigantic Nile perch, which may reach a length of five feet and weigh two hundred pounds. If the Nile perch is too large to be boated at once, the line is made fast to the canoe and the fish allowed to play himself out over a distance of many miles.

The lakes of Africa are not only important for their fish and their water supply. Salt is being precipitated from some of the more concentrated waters, and serves as an important item of commerce among native tribes. Agricultural peoples living on an exclusively vegetable diet have an especially heavy demand for salt, and a tribe lucky enough to have a salt lake in its territory does not need to fish or hunt or practice agriculture, but maintains itself on the manufacture and sale of salt.

The Valley of Mexico is another region in which lakes played a great role in the culture of primitive people. Maudslay's map of the Valley at the time of the conquest in 1521 gives an impressive picture of the density of population

FIG. 10. BANYORO METHOD OF FISHING

MAKING USE OF THE NATURAL FOOD CHAIN OF LAKE ALBERT. (A) BUNDLE OF REEDS IN WHICH HAPLOCHROMIS IS CAPTURED; (B) HAPLOCHROMIS; (C) HOOKED POLE, BAITED WITH HAPLOCHROMIS, FOR CAPTURE OF TIGER FISH; (D) TIGER FISH; (E) ROPE AND HOOK, BAITED WITH TIGER FISH FOR CAPTURE OF NILE PERCH; (F) NILE PERCH.

around the lakes at that time. It is true that the extraordinary civilization of the Mexicans was made possible by commerce and by tribute levied on the people of the entire country, and was not wholly supported by the Valley itself. Nevertheless the lakes served the inhabitants in a variety of ways. The waters of the fresh lakes abounded in edible fish and a tasty salamander, the axolotl, and their shallow marginal areas were the seat of a flourishing agriculture maintained on chinampas, or floating truck gardens. In the salt lake of Texcoco immense swarms of water bugs were collected, the dried insects being used as food for birds, while the eggs were collected from the bottom and from brush piles placed in the water for the purpose, and made into an edible cake "like cheese," the source of which puzzled the conquerors. And it must not be forgotten that for centuries the lakes served as effective moats for the protection of the island communities, of which Tenochtitlan, now Mexico City, was the most important. Only through the consummate skill of a great military strategist did this advantage become a tragic liability, when Cortez seized the causeways, cut the aqueduct and turned the city into a death trap.

The great lakes of the Valley have now been drained, with the exception of the shrunken remnant of Texcoco and the tortuous passages between the chinampas of Xochimilco. Some idea of the original Mexican lake culture may still be obtained, however, at Lake Pátzcuaro, two hundred miles west of Mexico City in the country of the Tarascans, whose ancient capital, Tzintzuntzan, on the shore of the lake, always maintained its independence of the powerful Aztec empire to the east. Pátzcuaro is not the largest lake in Mexico, but it is unsurpassed for beauty and interest. The modern Tarascans, particularly those of the island community Janitzio, maintain a fishing culture which must resemble in many respects that of the Aztec lake villages. Two principal types of gear are used, the first, the chinchorro, being a seine as long as 300 meters, operated offshore from several dugout canoes, and

The Macmillan Company

FIG. 11. TARASCAN FISHERMEN
WITH DUGOUT CANOES AND BUTTERFLY NETS, LAGO DE PATZCUARO, MICHOACAN, MEXICO.

the second the mariposa, or butterfly net, shown in Fig. 11. Several types of native fishes are caught, mostly members of the family Cichlidae, the same family which has produced so many endemic species in the African lakes. Some of these are small and live in the upper water like sardines, while the celebrated Pátzcuaro "whitefish" is larger and lives in the weeds. In addition the large-mouth black bass of the United States has been acclimated, and is called by the natives "trucha," or trout. The lake, like several others of the western plateau, is apparently a residual descendant of a large pluvial lake, and since its isolation several endemic species have been evolved, including one of the Cichlid fishes and a large salamander, which is also eaten by the Indians.

Of course I have not yet mentioned the Neolithic lake dwellers of Europe, or the many other lake cultures known to archeology. A tabulation of these, if one could be made, would doubtless show that the wide, swampy, lake-dotted valley has served many times in the history of the human race as a focus of civilization; aside from the Valley of Mexico, other examples are the upper Rhine valley, the basin of Lake Titicaca, and possibly Glastonbury, the British Iron Age site. A recent case in point is the Vale of Kashmir, where, to judge from Hutchinson's account, the use of floating truck gardens parallels to a remarkable degree that at Xochimilco. But there is no need for me to belabor the point. I shall be content if I have indicated, by means of this brief summary, something of the position of limnology in the ever-widening sphere of the geographic sciences.

NOTE: The foregoing article leans heavily on the work and ideas of Professor G. Evelyn Hutchinson, and much of it has been shamelessly borrowed from his copyrighted "Notes on Limnology," still in mimeographed form. Another large fraction has been taken from the excellent non-technical account of "The Inland Waters of Africa," by S. and E. B. Worthington, including Figs. 9 and 10.

CRYSTALLINITY IN CELLULOSE ESTERS

By Dr. W. O. BAKER

CHEMICAL LABORATORIES, BELL TELEPHONE LABORATORIES

Toughness, strength and flexibility of plastics extensively applied in communications, aircraft, and as metal substitutes for the defense program are influenced by the arrangement of their giant molecules as well as their composition, according to recent investigations of Bell Telephone Laboratories. Plastics contain molecules thousands of times larger than those of water or gasoline and in most cases these molecules are very long and threadlike. Hence they are frequently called chain or polymer molecules. Derivatives of cellulose are among the most important polymers which can be readily formed into any desired shape, much as metals are cast. Cellulose is the principal constituent of cotton and woodpulp, and hence its derivatives relate to products of economic and strategic importance, easily produced in this country.

The present investigation concerns chiefly certain compounds of cellulose, such as cellulose acetate and cellulose butyrate. These are used for electrical insulation, moldings of apparatus, photographic film, airplane dopes and lacquers. It was desired to discover the fundamental properties which make these materials resistant to shock, bending, twisting and dimensional change. The studies were undertaken on a molecular scale rather than with the usual engineering tests, and the high magnification necessary was obtained by photographing x-ray beams after they passed through selected samples of the plastics. These photographs differ from ordinary x-ray shadow pictures in that they give diffraction patterns which can be measured to show distances between the molecules as small as a billionth of an inch, and also to indicate how the molecules are placed with respect to each other in the solid.

The samples studied were small, flat sections about one mm thick. This small size facilitates examination of special parts from moldings, and even thinner films from lacquers. The samples were rigidly mounted on a lead insert, Figure 2, so as to cover a small cylindrical hole through its center, which formed a tiny pipe through which x-rays were guided, from the tube where they are generated, to the sample. When this minute cylindrical beam of x-rays passes through the plastic, much of it expands into a cone because the regular layers of molecules have diffracted it. Actually, there are often many coaxial cones, whose axes are along the original, unbent beam. These cones have a common apex at the point where the x-ray beam leaves the sample on its way to the photographic plate. After three or four hours exposure they appear on the developed photographic film as circles and the degree of crystallinity in the sample is shown by the sharpness and the number of circles recorded.

In striking analogy to the behavior of metals, it was found that the cellulose esters could be quenched by cooling them rapidly from the molten state. The long polymer molecules were then found to be disordered with respect to each other; that is, given faces of the molecules did not all point in the same direction throughout portions of the solids, as would occur in crystals. Neighbors of a given molecule are quite randomly arranged although there is a tendency for sections of the chains to lie side by

side. They are like a company of soldiers drawn up in formation except that the men as a whole face in all directions, rather than just to the front. When these plastics are cooled slowly from the melt, however, much greater order occurs, and it is as though little squads of men through the company stood at attention facing the same way in a given squad, although all the squads as units do not face in the same direction. The molecules have a very ordered arrangement in local regions throughout the plastic.

When the molecules in the plastic have the maximum disorder, the material tends to be most soft and flexible and when they are most ordered, or crystallized the material is hardest and strongest, but sometimes brittle. These extremes are illustrated by gum rubber, for instance, in which the molecules are disordered, while in ice or sugar, which are brittle, they are almost perfectly ordered. Evidently a compromise between these extremes is most desirable for toughness and general industrial utility. The x-ray studies show that various amounts of order and disorder can be produced in a given cellulose plastic by the quenching or tempering treatment.

Two other methods of controlling the number of organized and disorganized molecules have been long used in the technology of cellulose plastics, as work-

FIG. 1. X-RAY SPECTROMETER

FOR STUDYING THE CRYSTALLINE STRUCTURE OF MATERIALS. THE TUBE IS ENCLOSED IN A SHEET-LEAD HOUSING TO PROTECT THE OPERATOR FROM STRAY X-RADIATION.

ing procedures. The first is to control the shape of the cellulose ester molecules by the amount of the reaction and the nature of the substituting group so that they can only partially fit together to give an ordered array. By analogy, a few extremely fat men would cause the army squads to become locally disarranged, a desirable condition, at least in the plastic. The second, and this applies chiefly to lacquers such as airplane dopes and film formation, is selection of a particular solvent or mixture of solvents, which evaporates as the cellulose ester film dries. Various liquids were found to cause different amounts of molecular order in the resulting films. The analogy to the soldiers here is to imagine a company of them swimming about in a reservoir of water which is then drained so that the men settle toward the bottom. When they can finally stand there they may be found either disordered and facing in all directions or in intermediate degrees of organization, with some almost in parade formation. For the molecules, the degree of order in which the liquid leaves them has been found to depend largely on the nature of the liquid, and hence arises the technical importance of choosing the right solvents so that the films will not crack off flexing wires or vital airplane parts.

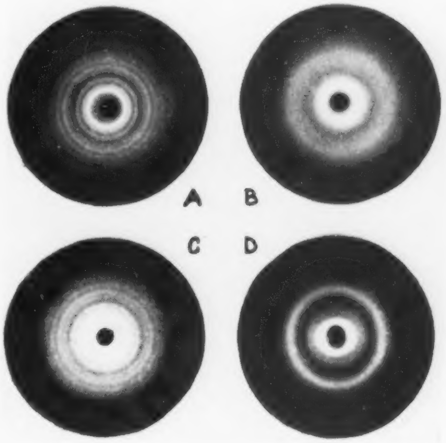


FIG. 3. CELLULOSE ESTER

X-RAY DIFFRACTION PATTERNS ARE SHOWN: (A) IN HIGHLY CRYSTALLINE CONDITION; (B) MOLECULARLY DISORDERED; (C) IN PARTIALLY CRYSTALLINE STATE, WHICH WAS OBTAINED BY ANNEALING THE SPECIMEN; (D) SIMILAR PARTIAL CRYSTALLINITY RESULTING FROM SOLVENT ACTION.

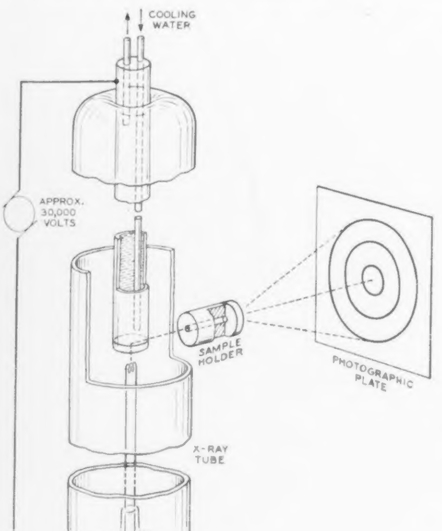
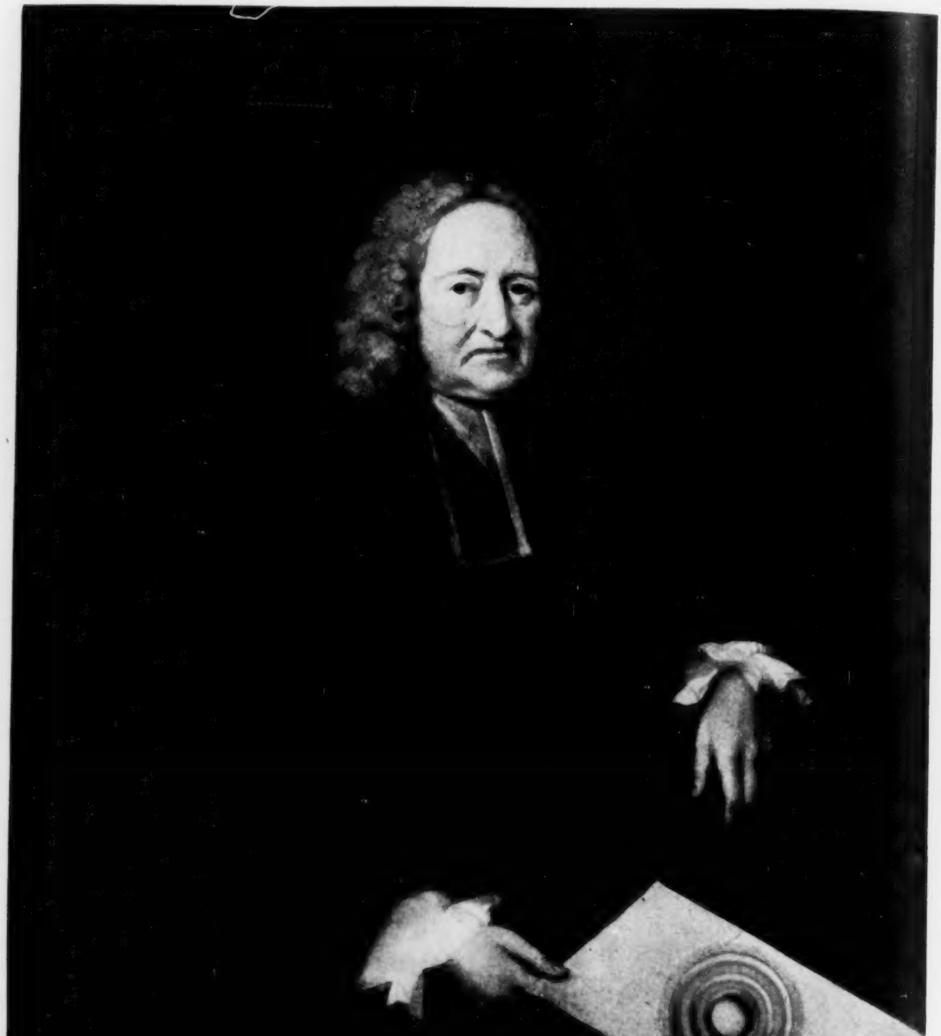


FIG. 2. X-RAY APPARATUS

IN X-RAY STUDIES OF THE CRYSTALLINITY OF CELLULOSE ESTERS A FINE STREAM OF THE RADIATION PASSES THROUGH THE SPECIMEN AND IS DIFFRACTED BY IT INTO A SERIES OF CONCENTRIC CONES WHOSE BASES ARE RECORDED AS CONCENTRIC CIRCLES ON A PHOTOGRAPHIC PLATE.

An interesting detail of the study was proof that sections of the plastic's molecules could move around and "come to attention" in ordered positions in the solid state. The molecules in solids are generally regarded as being fixed but it is now found that actually they undergo considerable torsional motion, under the influence of temperature. Thus, it was possible to anneal the quenched cellulose esters, and the x-ray patterns showed how this annealing process caused the chain molecules to take up ordered positions. This ability of portions of the molecules to move in plastic solids even at ordinary temperatures appears closely related to their plasticity and capacity to bend and return to the original form.



Emery Walker Ltd. ph. sc.

Edmond Halley

FROM A PORTRAIT BY M. DAHL IN THE POSSESSION OF THE ROYAL SOCIETY OF LONDON.

EDMOND HALLEY, 1656–1742

By Dr. N. T. BOBROVNIKOFF

DIRECTOR, PERKINS OBSERVATORY, OHIO WESLEYAN AND OHIO STATE UNIVERSITIES

EDMOND[1] HALLEY was born on November 8, 1656 (new style), at Haggerston in the parish of St. Leonard Shoreditch in the suburbs of London. His father was a prosperous business man, but subsequent losses greatly impaired his fortune. Nevertheless he gave his son an excellent education in St. Paul's School where young Halley became proficient in Latin, Greek, Hebrew, and mathematical sciences. At midsummer, 1673, Halley was admitted as a student of Queen's College, Oxford University. From this time on for some thirty years Halley's life was rich in events.

He published his first scientific paper on planetary orbits in the *Philosophical Transactions of the Royal Society* in 1676 when he was only 19 years of age. In November, 1676, he sailed for the Island of St. Helena in order to make observations of southern stars. He returned to Oxford in the fall of 1678 to receive the degree of Master of Arts. The usual formalities were dispensed with after King Charles II sent a letter to the university highly commending Halley for his work at St. Helena.

In the same year Halley was elected fellow of the Royal Society. He soon left London for a conference with Hevelius at Danzig concerning the best methods to be used in observations of the stars. It might seem strange to us, but Hevelius would not admit that telescopes were of any advantage in observing the positions of the stars. Halley tried to prove the advantage of the telescope, but apparently Hevelius would not change his opinion. Halley, however, developed a friendship with Hevelius and stayed in Danzig for two months. In December, 1680, he started on a trip to France and Italy, where he became acquainted with eminent scientists.

In 1682 soon after his return from Europe Halley married Mary Tooke, with whom he lived happily for 55 years until her death. Two daughters and one son were born to this marriage. At about this time Halley met Newton and formed a friendship that lasted as long as they both lived.

Between the years 1682 and 1696 Halley did not occupy any official position aside from being assistant secretary of the Royal Society. In 1684 Halley's father died under mysterious circumstances, and there was a litigation between Halley and his step-mother which very adversely affected Halley's financial status.

When Halley applied in 1691 for the Savilian professorship at Oxford, his orthodoxy[2] was questioned. Bishop Stillingfleet, who examined Halley, was not satisfied, and Dr. Gregory received the appointment.

[1] The correct spelling of the Christian name is Edmond not Edmund, although even Halley's contemporaries often used the latter spelling. There is no detailed biography of Halley. Some phases of his career would require considerable research in contemporary documents. In the preparation of this article, extensive use has been made of "Correspondence and Papers of Edmond Halley," arranged and edited by E. F. MacPike, Oxford, at the Clarendon Press, 1932.

[2] This point is not sufficiently appreciated by the modern historians of science. Whiston, the successor of Newton in Cambridge, was removed from his professorship and reduced to poverty on the charge of being Arian (*Phil. Trans. Roy. Soc.*, abridged, 6, 532, 1809). In the case of Halley there were other causes for the decline of his application, such as Flamsteed's animosity. Gregory certainly was not much better off than Halley in the matter of orthodoxy. There is a story about a Scot looking for Halley because he "would fain to see the man that has less religion than Dr. Gregory." (MacPike, *op. cit.*, p. 265.)

In March, 1696, Halley was appointed comptroller of the mint at Chester, an office which he held for about two years. At this time Peter the Great of Russia was in England, and Halley was introduced to him. Peter the Great conferred with him about the Russian navy and the development of sciences in that country and was so pleased with him that Halley was admitted "to the familiarity of his table."

In 1698 King William III appointed Halley commander of a ship, which bore the quaint name *Paramour Pink,* with orders to investigate the variation of the magnetic needle in the South Atlantic Ocean and to "call at His Majesty's Settlements in America, and make some observations there, in order to the better laying down in Longitudes and Latitudes of those places, and to attempt a discovery of what Lands lay to the South of the Western Ocean." Halley set out on his voyage on November 5, but on crossing the equator there was mutiny on the ship and Halley returned to England in June, 1699. According to the official letter of June 23, 1699, from Halley to Josiah Burchett, Secretary to the Admiralty, Halley's Lieutenant Harrison "was pleased so grossly to affront me, as to tell me before my Officers and Seamen on Deck . . . that I was not only incapable to take charge of the *Pink* but even of a Longboat; upon which I desired him to keep his Cabbin for that night, and for the future I would take the charge of the Shipp my self to shew him his mistake: and accordingly I have watcht in his steed ever since, and brought the Shipp well home from near the banks of Newfound Land, without the least assistance from him."[3]

Halley was evidently considered by the admiralty as a captain with full authority and not merely as a scientific observer. After the court martial of his lieutenant, Halley sailed again on board the same ship. The story of Halley's adventures is told by him in his letters to the admiralty. They throw much light on Halley's character as well as on conditions prevailing at sea in his time. On the first voyage Halley called at the Cape Verde Islands where the *Paramour Pink* was fired upon when it was taken for a pirate ship. After some adventures in Brazil the mutiny referred to above occurred. On the second voyage Halley called at Madeira, St. Helena, and Rio de Janeiro. From there he sailed to the latitude S 52 1/2° where he "fell in with great Islands of Ice, of soe incredible a hight and Magnitude that I scarce dare write my thoughts of it."[4] After the dangers of navigating among ice-fields, the ship finally reached the Islands of Tristan da Cunha and sailed back to St. Helena. From there Halley went to Trinidad and Pernambuco where he was nearly arrested by the British consul when he was suspected as a pirate. At Barbados Halley and his men fell sick with a "severe pestilentiall dissease."[5] As one letter from Halley is dated July 8, 1700, at Bermuda and the next is dated August 27, Plymouth, England, it does not appear that he paid any visit to the American Colonies, although he sailed to Plymouth by way of Newfoundland.

Soon after Halley's return from his second voyage, he was appointed to proceed in the same ship, the *Paramour Pink,* "to observe the course of the Tides, in the Channel of England, in every Circumstance thereof; and to take the bearings of the principal head Lands, in order to lay down the Coast truly."[6]

In 1702 he was sent by Queen Anne to Austria in connection with the organization of seaports on the Adriatic. Halley was presented to Emperor Leopold, "who was exceedingly pleas'd with him, presented him with a Fine Diamond

[3] MacPike, *op. cit.,* p. 107.

[4] *Ibid.,* p. 113.

[5] *Ibid.,* p. 114.

[6] The Admiralty's instructions to Captain Halley were dated June 12, 1701.

Ring, and sent a letter by him to the Queen." This business required another trip to Austria on which again Halley met royalty, this time the Electoral Prince, afterwards King George II, and the Queen of Prussia.

After Halley's return to England in October, 1703, he was appointed Savilian professor at Oxford, in which capacity he was connected with his alma mater until 1719. The only external event to be noticed during this time is Halley's election as secretary of the Royal Society in 1713. The connection with Oxford was, however, the most fruitful period of Halley's scientific activity. In 1719 Halley was appointed Astronomer Royal and remained at this post until his death in 1742.

Looking over Halley's contributions to science, one is amazed at his versatility. His published writings include about 100 items,[7] mostly on astronomical subjects but including also papers on mathematics, statistics, physics, geophysics and history. There are also thirty papers[8] never printed but reconstructed from rough drafts. They were read at various times before the Royal Society. These papers are mostly on physics, although here we meet with subjects more unusual for astronomers such as the height and velocity of bullets, diving bells, force of winds, a method enabling a ship to carry its guns in bad weather, and ancient geography. The full extent of Halley's scientific interest, however, is revealed by the extracts from the journal books of the Royal Society referring to Halley.[9] No papers or notes are left on which these exceedingly numerous reports of Halley to the Society were based. We find Halley discoursing about mathematical problems, unusual plants of St. Helena, ancient measures of weight, fossil shells found by him on Harwich Cliff, a new remedy for some disease of the skin, cuttlefish and flounders, microscopic examination of crystals, observations on the explosion of gun-powder, hurricanes, growth of trees, identification of Roman towns in Great Britain, lobsters and crabs, and a multitude of other topics besides, of course, astronomy and physics. These reports cover the years 1687 to 1696, after which date they stop abruptly.[10]

If we recall that Halley knew and used Latin, Greek and Hebrew and that when he needed Arabic for his translation of ancient treatises[11] he learned it, too, we are not surprised at Newton's reference "to the most acute and universally learned Mr. Edmund Halley."[12]

It is to be feared, however, that even in Halley's time the whole realm of human intellectual endeavor was too much for one man. What is gained in breadth is lost in depth. Halley did not possess either the profundity of Newton or the meticulousness of Flamsteed, and therefore most of Halley's discoveries are flashes of genius without the substantial groundwork.

[7] A list is given by MacPike, *op. cit.*, p. 272.

[8] *Ibid.*, p. 135.

[9] *Ibid.*, p. 210.

[10] MacPike evidently considers all these reports as originating from Halley. He quotes with approval the remark of Mr. H. W. Robinson who copied these extracts that one is "astonished at the variety of subjects dealt with . . . which give an entirely broader view of Halley's interests." It is not possible to say which ones were Halley's own papers and which ones he perhaps merely read in his capacity as assistant-secretary of the Society. Practically all notes begin, "Halley read a paper . . . ," but some notes state definitely that Halley himself was the author while others do not. The above enumeration of the subjects refers to the cases in which Halley's authorship is certain. It would be truly remarkable if observations of human anatomy and physiology referred to in some of these notes were also due to Halley! A future biographer of Halley would do well to investigate why these reports cover only nine years.

[11] Apollonii Pergaei de Sectione Rationis Libri Duo ex Arabico MS. Latine versi. . . . Opera & Studio Edmundi Halley, Oxonii, 1706. Menelai Sphaericorum libri III, quos olim, collatis MSS. Hebraeis et Arabicis, typis experimendos curavit. . . . E. Halleius, Oxonii, 1752.

[12] Preface to the first edition of the *Principia*.

Among these discoveries some have proved of great importance in science. Such, for instance, was the secular acceleration of the moon's motion found by him in his study of ancient eclipses.[13] Halley could not prove it, although he was sure of it. Later this effect was shown to be due to the retardation of the axial rotation of the earth owing to oceanic tides. Another discovery of Halley's, that of proper motions of the stars, became of fundamental importance to our knowledge of the sidereal universe. Halley merely noticed[14] that the positions of the stars Arcturus, Aldebaran, and Sirius had changed as compared with their positions in antiquity. The great significance of this discovery apparently escaped Halley who thought that perhaps the obliquity of the ecliptic had changed. His third discovery of potentially great value was the possibility of estimating the age of the world by the amount of salt in the ocean.[15] This method is at best approximate, but even rough calculations would have shown that the ocean must be millions of years old. Whether Halley made the necessary calculations is not known, but he remarks at the end of his article that "perhaps . . . the world may be found much older than many have hitherto imagined." Such reflections might well seem impious in an age when John Lightfoot, Vice-Chancellor of Cambridge University, demonstrated that "heaven and earth, centre and circumference, were created together in the same instant" and that "this work took place and man was created by the Trinity on the twenty-third of October, 4004 B.C., at nine o'clock in the morning."[16]

Halley's contributions to the subject of terrestrial magnetism were of great importance. As a result of his voyages, he constructed magnetic charts indispensable in navigation. His numerous observations of meteors, aurorae, eclipses, etc., must also be mentioned. It is to be noted that he could not discard the ancient idea that meteors were terrestrial exhalations set on fire in the heavens.[17] He definitely linked aurorae[18] with terrestrial magnetism and thought them to be analogous to an electric discharge in accordance with modern views. Describing[19] an eclipse of the sun in 1715, he mentioned and correctly interpreted the phenomenon known now as Baily's beads supposed to have been discovered in 1836.

Halley's most famous discovery was the periodicity of the comet observed by him in 1682.[20] Applying Newton's theory of gravitation to this comet, he showed that its path around the sun was substantially the same as that of the comets observed in 1607 and 1531. On further examination of records, he found that comets were also observed in the years 1456, 1380, and 1305. Accordingly, this comet must have a period of about 76 years and must return to the sun either at the end of 1758 or the beginning of 1759. Halley even allowed for the perturbation of Jupiter which retarded the perihelion passage of the comet in 1759.

The comet, now known as Halley's Comet, was in perihelion in 1759 and again in 1835 and 1910. Its previous apparitions have been traced down to 467 B.C. Comets, the prodigies and omens of the Middle Ages, were shown to obey the law of gravitation, and science could predict their motions. The impact of Halley's successful prediction upon the minds of those who watched the return of his comet in 1759 was great. Halley knew that he could not hope to live to see the comet again and said, "If it

[13] *Phil. Trans. Roy. Soc.*, 19, 160, 1695–7.

[14] *Phil. Trans. Roy. Soc.*, 30, 736, 1717–19.

[15] *Phil. Trans. Roy. Soc.*, 29, 296, 1714–16.

[16] A. D. White, "A History of Warfare of Science with Theology," Appleton and Co., 1920, vol. I, p. 249 ff.

[17] *Phil. Trans. Roy. Soc.*, 29, 159, 1714–16.

[18] *Phil. Trans. Roy. Soc.*, 29, 406, 1714–16.

[19] *Phil. Trans. Roy. Soc.*, 29, 245, 1714–16.

[20] *Astronomiae Cometicae Synopsis*, Oxon., 1705.

should return, according to our predictions, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman."

Halley, the universal genius, has left indelible traces in the history of astronomy. His ability to derive correct conclusions from the often inadequate data at his disposal was phenomenal. He was not given to idle speculation as were most of his contemporaries.[21] In fact his analysis[22] of the measurement of stellar diameters by Cassini is a fine example of scientific criticism.

In only one branch of astronomy, astrometric measures, Halley's contributions are not impressive. He had the correct idea as to the method of determining the parallax of the sun by the transits of Mercury and Venus, but his own attempts to observe Mercury on the disk of the sun resulted in a very poor figure for the parallax. However, he drew the attention of astronomers to the importance of the transit of Venus in 1761 and predicted the circumstances of the phenomenon with a good degree of accuracy considering his means of information.

As has been mentioned before, Halley at the age of 20 conceived the idea of forming a catalogue of southern stars invisible from the latitude of central Europe. King Charles II was pleased with the project and gave Halley a letter of recommendation to the East India Company. This company agreed to transport the astronomer to the Isle of St. Helena and to provide him with proper accommodations. Halley's father allowed him £300 per annum for the necessary expenses. Halley spent about two years on this journey (1676–78) of which at least a half year was spent at sea.

Halley's main instruments were a brass sextant with a radius of $5\frac{1}{2}$ feet and fitted with telescopic sights, a quadrant with a radius of about 2 feet, a telescope 24 feet in length, and a good pendulum clock. On arriving at the island he was disappointed to find climatic conditions much worse than he had been led to believe, and consequently he determined the positions of only 341 stars. This work was published in 1679 under the title *Catalogus Stellarum Australium*.

In order to appreciate the importance of this attempt, we must remember that at the end of the seventeenth century there were no catalogues of southern stars. Some observations by Americus Vespucius, Andrew Corsalio, and other navigators were collected by Peter Theodore and were made use of by Bayer in 1603 for his charts of the constellations, and in 1624 James Bartsch published a catalogue of 136 southern stars also based on casual observations by navigators. The necessity, therefore, of a more correct and larger catalogue was obvious both from the viewpoint of science and from practical needs of navigation. The task which Halley set for himself was timely and important and gives credit to the acumen of so young a man.

The results, however, were definitely disappointing both in quantity and quality. The title of "the Columbus of the Southern Sky"[23] must be reserved not for Halley but for Nicolas Louis de Lacaille who, beginning in 1751 at the Cape of Good Hope, within 14 months observed the positions and brightness of no fewer than 9,766 stars. Flamsteed, the first Astronomer Royal, eminently qualified to pronounce judgment on astrometric work, was not of a flattering

[21] To be sure, Halley tried to explain some peculiarities of the earth's surface by the action of comets and was wondering about the primeval light in connection with nebulae, but all this was mild in comparison with vagaries of Whiston (*A New Theory of the Earth*, Cambridge, 1708).

[22] *Phil. Trans. Roy. Soc.*, 31, 1, 1720–21.

[23] B. A. Gould, *Uranometria Argentina*, *Res. Obs. Nac. Argentina*, 1, 1879.

opinion of Halley's catalogue in spite of his earlier and perhaps ironic reference to Halley as "our southern Tycho." It does not appear that the catalogue was of much use even to the mariners.[24] It was in no sense a fundamental catalogue but merely consisted of differential measures of new stars in reference to stars already observed by Tycho. Halley himself called his catalogue a "*supplementum Catalogi Tychonici.*" This catalogue of southern stars was, however, the foundation of Halley's fame.

I have dwelt at some length on this piece of work by the youthful Halley because it illustrates his inherent weakness as a practical astronomer: his brilliancy of conception and inadequacy of execution. That he was an arduous observer can not be doubted. If we consider the closing years of his career, Halley, as Astronomer Royal, according to his anonymous biographer,[25] observed from 1722 to 1740, "during all which time he has scarcely ever lost a Meridian View of the Moon, either by Day or Night, when the Heavens would permit her to be seen." Yet the desire to observe does not of itself make a good astronomer. Halley evidently lacked the ability to pay sufficient attention to the minutest details which are so important in astronomy of position.[26] Perhaps he was too brilliant for that.

[24] The catalogue was reprinted by F. Baily in *Memoires of the Royal Astronomical Society*, vol. 13, 1843. In his introduction Baily refrains from any criticism of Halley's work, but the mere fact that Halley's catalogue was included among the "ancient catalogues" of Ptolemy, Ulug Begh, Tycho Brahe, and Hevelius is significant.

[25] Probably Martin Folkes, president of the Royal Society, 1741–52. See MacPike, *op. cit.*, p. vi.

[26] De Morgan remarked: "The period during which he held the post of Astronomer Royal, compared with those of his predecessor Flamsteed and his successor Bradley, is hardly entitled, if we look at its effect upon the progress of science, to be called more than a strong twilight night between two bright summer days."—MacPike, *ibid.*

Observations of the moon during the nineteen-year period of the revolution of its nodes were necessary and highly desirable, but the results of Halley's observations were never published. They exist in the form of four notebooks full of extraneous matter and sometimes unintelligible. According to Baily,[27] neither Halley nor anybody else could make the slightest use of them. Often it is impossible to say with which instrument the observations were made or which clock was used. The errors of the quadrant were not determined, and the clocks were very inaccurate. As Baily says, ". . . it will undoubtedly sound strange to the modern astronomer to be informed that one cause of the irregularity of the clocks arose from the bob of the pendulum striking against the sides of the clock case."

The reader should be reminded, however, that Halley was appointed Astronomer Royal in 1720 at an age when in our time most scientific workers begin to think of retirement. The observations in question were made by Halley between the age of sixty-four and eighty-six.

Halley's name will always be connected with one of the greatest works of human genius, "Philosophiae Naturalis Principia Mathematica," by Isaac Newton. In the preface to the first edition[28] Newton pays a handsome tribue to Halley who "not only assisted me in correcting the errors of the press and preparing the geometrical figures, but it was through his solicitations that it came to be published; for when he had obtained of me my demonstrations of the figure of the celestial orbits, he continually pressed me to communicate the same to the Royal Society, who afterwards, by their kind encouragement and entreaties, engaged me to think of publishing them."

The story of the publication of the "Principia" and Halley's rôle in it is

[27] *Mem. Roy. Astr. Soc.*, 8, 169, 1835.

[28] "Sir Isaac Newton's Mathematical Principles," etc., Univ. of California Press, 1934.

well told in a recent biography of Newton by L. T. More[29] which makes use of many documents hitherto unknown. Suffice it to say that Halley not only jarred Newton out of his inactivity but also supervised the printing of the book from the beginning to the end. Even more than that, since the Royal Society was in a poor financial condition, Halley financed the whole publication although he was by no means a wealthy man. He was glad to accept a position as assistant to the secretaries of the Society at a stipend of £50. Even this small sum sometimes was not paid in cash but in the form of unsaleable books published by the Society. Evidently Halley considered it worthwhile to undergo financial embarrassment in order to ensure the publication of the "incomparable treatise."[30] No wonder that Newton, deliberating upon the title of the book, wrote to Halley, ". . . I retain the former title. 'Twill help the sale of the book, which I ought not to diminish now 'tis yours."[31] Fortunately the *Principia* sold well, and Halley does not appear to have sustained any financial loss.

Halley is described by his contemporaries[32] as "of a middle stature, inclining to tallness, of a thin habit of body, and a fair complexion"; ". . . he always spoke as well as acted with an uncommon degree of sprightliness and vivacity." Several portraits of Halley are in existence. The one reproduced in this article represents Halley at the end of his career when he was eighty years old.[33] The influence of Halley on his contemporaries must have been great both by his published researches and in private conversation. He was generally liked and admired with one conspicuous exception. That exception was Flamsteed, Astronomer Royal and predecessor of Halley in that post. The quarrel between Flamsteed on one hand and Halley and Newton on the other constitutes a blot on the memory of these great men. The bitterness shown by Flamsteed toward Halley, who was "not ashamed to borrow where he can, but he blushes whenever he is forced to acknowledge it,"[34] was extraordinary. Flamsteed had "no esteem of a man who has lost his reputation, both for skill, candour, and ingenuity, by silly tricks, ingratitude, and foolish prate: and that I value not all, or any of the same of him and his infidel companions. . . ."[35] The climax of the quarrel was reached when Halley was appointed to act as editor of Flamsteed's "Historia Coelestis," which was published in 1712 at which time most of the edition was burned by its irate author. This book was finally re-published in 1726 after Flamsteed's death.

It would take us too far afield to consider this quarrel in detail. It is sufficient to say that Flamsteed was not the only one to blame. The animosity between Halley and Flamsteed was greatly enhanced by their utterly different personalities. Halley was a brilliant man of the world, accepted by royalty and well known in scientific circles at home and abroad. Flamsteed was a conscientious plodder, shut up in his observatory and in poor health. Being a clergyman, he naturally considered Halley's skepticism of the Bible as atheism. The charge of atheism in so far as Halley is concerned does not come from Flamsteed only, but there is little to substantiate it.

29 Isaac Newton, Charles Scribner's Sons, N. Y., 1934.

30 Letter of Halley to Newton of May 22, 1686, More, *op. cit.*, p. 305.

31 Letter of Newton to Halley of June 20, 1686, More, *op. cit.*, p. 309.

32 MacPike, *op. cit.*, p. 261.

33 This portrait is reproduced as a frontispiece in MacPike's book.

34 Dreyer, Flamsteed's Letters to R. Towneley, *Observatory*, 25, 280, 1922.

35 Letter of Flamsteed to Newton of February 24, 1691–2, More, *op. cit.*, p. 364. The reader, however, must make allowance for the temper of the times. Flamsteed later was just as bitter toward Newton, and Newton did not mince words about Robert Hooke.

Halley enjoyed robust health almost until the end of his days. For a few years before his death he suffered from partial paralysis, but he continued to observe until the last few months. He died on January 25, 1742, and was buried in the church yard of St. Margaret, Lee, near Greenwich. Halley's grave was restored in 1854, and the original tombstone was removed to Greenwich where it was let in the wall of the Royal Observatory.

The two centuries that have elapsed since Halley's death allow us sufficient perspective to estimate his place in the history of science. He dazzled his contemporaries by his remarkable erudition, yet he was great enough to subordinate his own considerable talent to the transcendent genius of Newton. Halley's contributions to astronomy, geodesy, navigation, meteorology, and terrestrial magnetism did not produce a revolution in science comparable to the publication of the *Principia,* but his contributions were for the most part of first rank. Above all he was the true son of his age when the rapidly accumulating data of new science made an irresistible appeal to men to draw conclusions which could not be verified until many years later. The fact that most of Halley's generalizations were correct in striking contrast with the wild guesses of some of his contemporaries shows the greatness of the man.

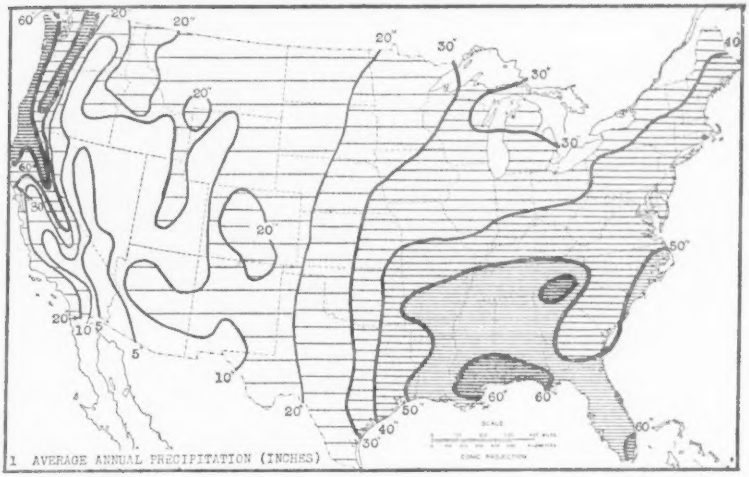
AVERAGE PRECIPITATION CONTRASTS IN THE UNITED STATES

By Dr. STEPHEN S. VISHER
PROFESSOR OF GEOGRAPHY, INDIANA UNIVERSITY

THE range in the United States in average annual precipitation is from 1.5 inches at Greenland Ranch, Death Valley, California, to 128.6 inches at Quinault, near Gray's Harbor, Washington, among the long-established Weather Bureau Stations. A score of other stations with records covering more than 20 years have annual averages of less than 4 inches or over 100 inches. The dry ones are in the Southwest (California, Nevada and Arizona) and the wet ones in western Washington and western Oregon. The greatest average precipitation east of the Coast Ranges is recorded by two stations in the mountains of western North Carolina which have long-time averages of about 83 inches.

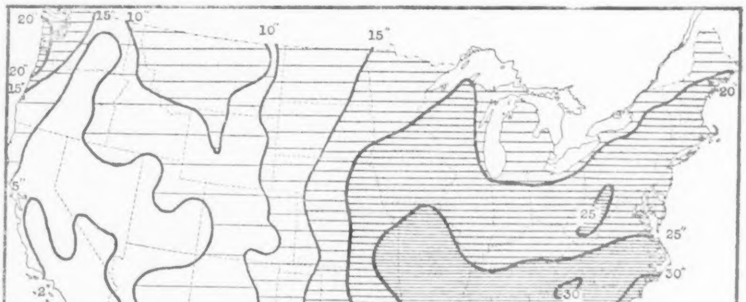
The accompanying Map 1 shows that little of the country receives an annual average of more than 60 inches of precipitation. In nearly one half of the country, less than 20 inches usually is received; nearly a fourth usually receives less than 10 inches a year; in about a sixth, mostly in the Southeast, more than 50 inches is normal. This map, and the others of this article, are shaded redrawings, with some simplification, of maps in the 1941 Yearbook of Agriculture, briefly discussed in the previous article of this series. The Yearbook maps were made under the direction of J. B. Kincer, of the U. S. Weather Bureau. They are based on the data accumulated during 1899–1938 at about 5,000 stations.

Map 2 shows the amount of precipitation received during the normal warmer half-year (April–September inclusive). It indicates that in that half-year, most of the West receives less than 10 inches, about half of it less than 5 inches, and a considerable area less than 2 inches. The largest amounts of rain are received

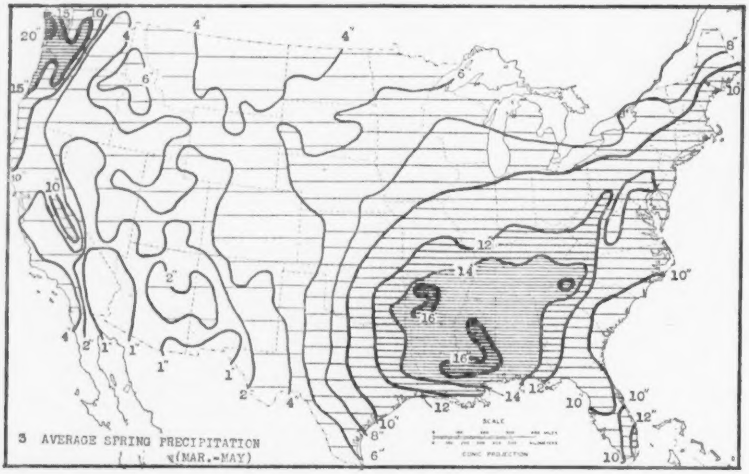


1 AVERAGE ANNUAL PRECIPITATION (INCHES)

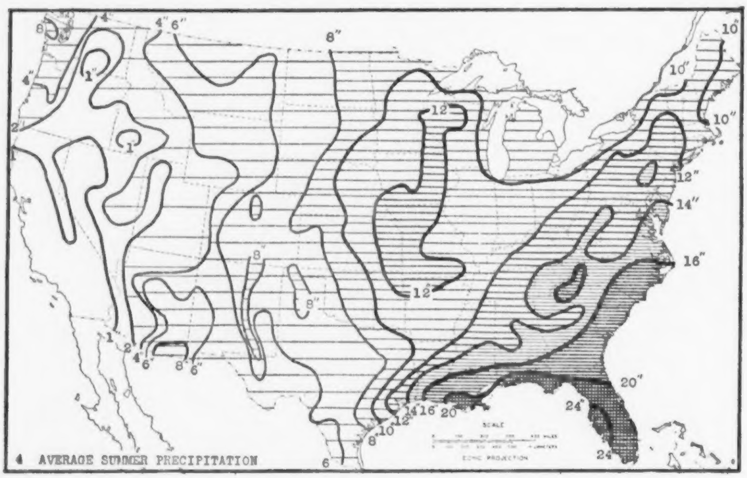
near the eastern margin of the Gulf of Mexico, from which area there is a gradual northward and a sharp westward decline. These decreases partly reflect increased distance from the great source of moisture for most of the eastern half of the United States—the Gulf of Mexico. The moisture is carried northward by "tropical air masses" blowing into eastward-moving cyclonic depressions or Lows which cross the country most frequently north of its middle. The relatively heavy warm-season rainfall of southern Florida is chiefly due to thunderstorms, many of them associated with tropical cyclones of which the most severe are hurricanes. The relative dryness of the West is partly due to the fact that during the warm season, cool winds from off the Pacific become warmed as they blow over the warm land and hence usually are able to retain their moisture. Cyclonic disturbances and thunderstorms, in which the air rises to sufficient heights to induce precipitation, are generally almost lacking in the Pacific Coast states during the warmer half-year. Altitude effects are evident in the southern Appalachians and in the Northwest; just west of the Coast Ranges and Cascades there is relatively heavy rainfall, but just east there is little.



2 AVERAGE WARM-SEASON PRECIPITATION (APRIL-SEPT.)



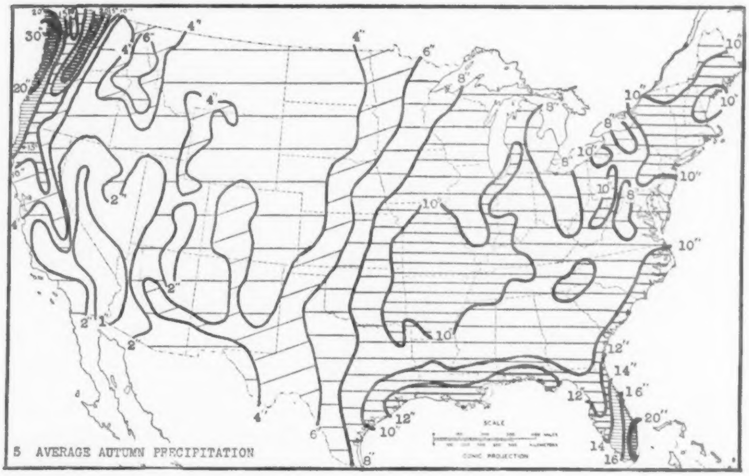
3 AVERAGE SPRING PRECIPITATION (MAR.-MAY)



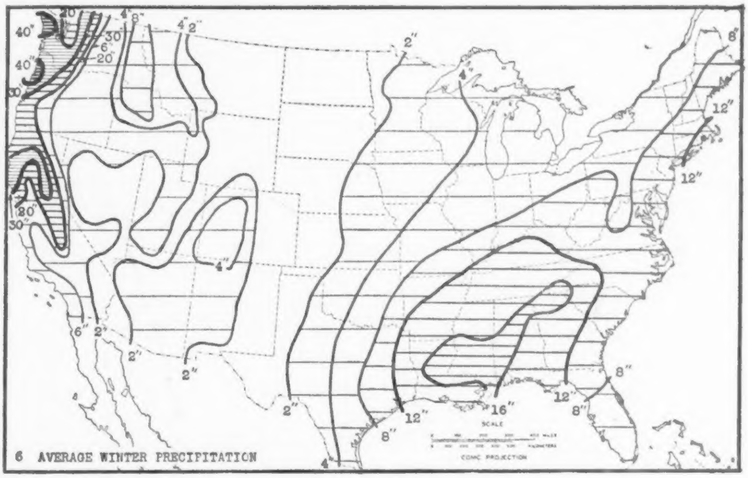
4 AVERAGE SUMMER PRECIPITATION

Maps 3–6 show the average precipitation in each of the four quarters of the year. Spring (Map 3) is a relatively wet season, especially in the lower Mississippi Valley and in the Northwest, where more than 14 inches are received, or an average of more than an inch a week. The driest region is the Southwest. From an area near the mouth of the Mississippi River, this map shows an almost steady decline northward, westward, eastward and even southeastward to southern Florida. Exceptions to this steady decline are caused by the southern Appalachians and the southern Ozarks.

During the summer (Map 4) the heaviest rainfall (16 inches or more) is close to the eastern part of the Gulf of Mexico and in the southern Appalachians. An area of heavier than average precipitation extends, however, from the Ozarks to Wisconsin. California is almost rainless and most of the Northwest receives less rain than the Great Plains. The Great Lakes region receives appreciably less rain than do areas a short distance away. This is due to the fact that in summer the lakes are relatively cool, which coolness interferes with the development of thunderstorms. More-



5 AVERAGE AUTUMN PRECIPITATION

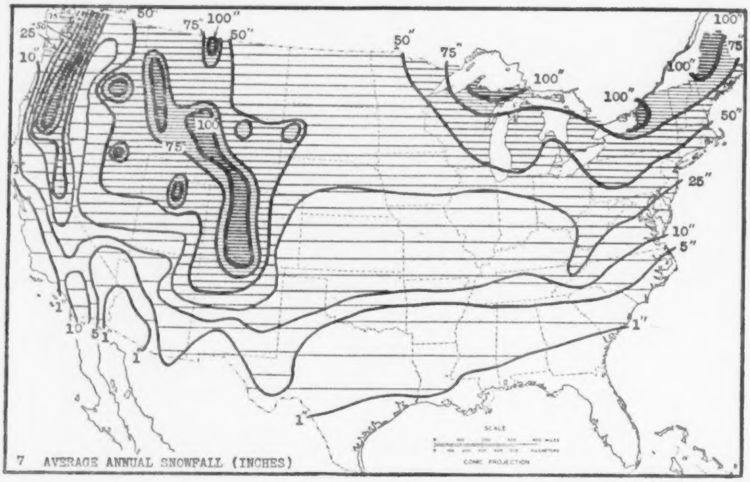


6 AVERAGE WINTER PRECIPITATION

over, winds blowing from the lakes over the warmer land have their capacity for moisture increased thereby.

During the autumn (Map 5) there is a sharp increase in the amount of precipitation near the Pacific Coast but a decline in most of the country. The central area receiving more than average for its region has shifted southeastward from its position in the summer and centers over southeastern Missouri rather than over southern Iowa. A curious northern prong of that relatively rainy area extends to western Michigan, apparently a result of the fact that the winds off Lake Michigan are sometimes sufficiently cooled in autumn by blowing over the adjacent land to cause appreciable local precipitation. The greater rainfall close to the coast of the Gulf of Mexico and the south Atlantic reflects the presence of tropical cyclonic disturbances, most of which yield much more rain on the coast than a short distance inland. Such tropical cyclones are most frequent in late summer or autumn and at that time are common enough, especially in Florida, to affect the average rainfall totals.

During the winter (Map 6) practi-

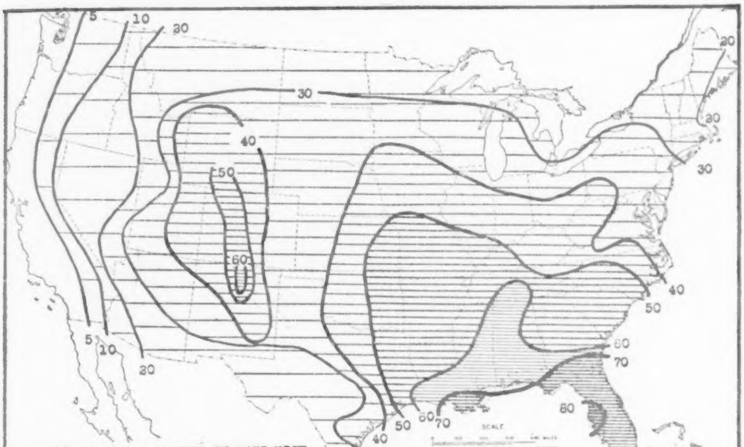


7 AVERAGE ANNUAL SNOWFALL (INCHES)

cally all the country except the Pacific Coast states and part of the Southeast receives less precipitation than during any other season. The central area of more than average precipitation noted in summer and autumn has shifted still farther southeastward, centering in southern Mississippi, somewhat southeast of its position in spring. The general prevalence of westerly winds in winter helps to explain the slight effect of the Atlantic Ocean. A conspicuous feature of this map is the wide west-central belt extending from Mexico to Canada, where less than 2 inches of precipitation is received in winter. The dryness of the winters of that region is a major cause of their grass-cover.

Much of the winter precipitation in the northern part of the country is snow. Map 7, of the average annual depth of snowfall, shows that the average amount of snow increases with latitude, except for Montana, which receives less than Colorado. Along the Gulf Coast less than an inch of snow falls during a normal winter while along the Canadian border several areas receive more than 100 inches (part of which falls in autumn and spring). The influence of the Great Lakes in increasing snowfall to the leeward is indicated. An area just east of Lake Ontario receives 150 inches on the average, more than any other lowland area in the United States. Several western mountain areas receive, however, more than 100 inches, and a part of the Cascades more than 300 inches. The greater snowfall in Colorado than in Montana is partly because more moisture is available, from the Gulf of Mexico, and partly is due to its greater average altitude.

The final map of this series (Map 8) deals with the number of thunderstorms. Such storms are almost synonymous with rain. During the summer they are fairly frequent throughout the entire country except the Pacific Coast, but during the cooler months they are much more common near the Gulf of Mexico than further north. Indeed they are rare or almost lacking in winter in the north. Thunderstorms occur on about a fifth of the days of the year in Florida, some of which days have two such storms. The relatively numerous thunderstorms in the central and southern Rocky Mountains is a conspicuous feature of this map. There they are limited to the summer. A map, not published here, of the annual number of days with damaging hailstorms, shows that hail is much less frequent in Florida than in the western



8 AVERAGE ANNUAL NUMBER OF DAYS WITH THUNDERSTORMS

area with many thunderstorms. In Florida, hailstorms usually damage any area less than once a crop season, in contrast with 4 to 6 times in a large western mountain and High Plains region. Presumably hail is formed in the most violent thunderstorm of the southeast, but at such great altitude that it is usually melted before reaching the ground. In the part of the West where damaging hailstorms are most frequent, the elevation of the ground above sea level averages more than 5,000 feet. A belt some 300 miles wide along the Atlantic and Pacific coasts has fewer than 2 damaging hailstorms a year in each locality. About half of the country, west of the Mississippi River and north of Louisiana, has an average of 3 or more. Hail storms are less frequent along the Canadian border than farther south, just as are thunderstorms.

Calculations by Kincer indicate that the average annual precipitation of the western third of the country, from the Pacific to the Rockies, is 18 inches; the average for the zone from the Rockies to the Mississippi River is 28 inches; the average for the region east of the Mississippi River is 43.5 inches. For the country as a whole (weighted State averages), the normal amount is 29 inches.

The amount of precipitation in any region depends upon two main conditions: the amount of atmospheric moisture, and the frequency and adequacy of the cooling of large volumes of air sufficiently to cause precipitation. The great source of atmospheric moisture is the sea, especially warm bodies of water from which there is much evaporation. For the United States east of the Rockies, the great source of moisture is the Gulf of Mexico. The agency that transports the moisture to the land is, of course, the wind. Most of the surface winds of the United States are cyclonic, and most of the rain-bringing winds spiral into Lows. Sufficient cooling to cause precipitation is accomplished in three chief ways: having the wind blow against mountains (orographic rain) or override cold bodies of air or to rise in thunderstorms. Warm moist air which blows northward into higher latitudes is cooled thereby, especially if it blows over cold land. In the United States, however, southerly winds seldom cause precipitation except where one of the three conditions just mentioned is present.

The distribution of precipitation in the United States shown by Maps 1–7 reflects regional contrasts in the operation of the several agencies or conditions

just mentioned. The general northward decrease in the eastern part of the country is largely due to increased distance from the Gulf of Mexico; the decline from the Pacific eastward to the Great Plains likewise reflects the inability of moisture from the ocean to reach far inland. The decline is especially abrupt because of the nearby mountains, just east of which there is little rain. The effect of mountains in increasing precipitation on their windward slopes is strikingly shown on the western slopes of the Coast Ranges, the Cascades and the Sierra Nevadas, but is also evident in the southern Appalachians and in the Rockies. The influence of thunderstorms as a cause of local convectional cooling is shown by the general correspondence between the frequency of such storms and the annual amount of precipitation. (Compare Maps 1 and 8.) Two departures from this general correspondence are the Pacific Coast, where there is much rain but few thunderstorms, and the southern Rockies, where there are many thunderstorms but not much rain. The scarcity of thunderstorms near the Pacific correlates with the general lack of warm-season rainfall. Many of the thunderstorms of the Rockies are "dry storms" yielding little rain, but often starting forest fires by their lightning.

The seasonal shiftings of the somewhat central region of more than average precipitation is one of the interesting features of Maps 3–6. These shiftings reflect seasonal changes in average temperature. In the summer, the continental interior becomes relatively warm, below-average air pressures develop, and inflowing winds result. These inflowing winds bring moisture, part of which is precipitated in convectional thunderstorms. As most of these thunderstorms develop in eastward-moving cyclonic depressions or Lows, most rain occurs to the southeast of the warmest part of the continent. As the months pass, the continent cools off until in winter its center is quite cold as compared with the ocean. Then it has relatively high average air pressure, and usually out-blowing winds. As a result, the continental interior is relatively dry in winter. Cyclonic disturbances often cross the United States in winter, but the southerly winds they cause are unable to draw much moisture far inland; instead, it is dropped in the South where it is first sharply cooled as it blows northward. The seasonal shifts in the Mississippi Basin area of above-average precipitation therefore clearly reflect the regional contrasts in seasonal temperatures and the differences in air pressure and winds resulting therefrom.

The pronounced regional contrasts in average precipitation depicted by these maps have profound influences upon plants, animals and mankind. The responses are, however, to the actual amounts of precipitation received, not to the average amounts. Hence any discussion of the responses logically follows a description of the subject of the next little article of this series, "Precipitation Variation in the United States."

FOOD HABITS OF PRIMITIVE MAN

II. FOOD—BIOLOGY OR BELIEF

By Dr. MARK GRAUBARD
THE PHYSIOLOGICAL LABORATORIES, CLARK UNIVERSITY

Taboos Affecting a Variety of Food Items

The taboo against the hen and her eggs somehow became established in large regions of Africa and Asia. Complete prohibition rules over the Wahuma, Wanyamwezi, Ujiji, the Gallas, Somalis and many other tribes. In India too the hen is considered an abomination and its meat tabooed. Mongols also abhor all birds and fish. Elsewhere the prohibition appears in variously modified forms. In Ashanti only girls before puberty may not eat eggs, which they taste for the first time amidst elaborate ceremonies as part of their puberty rites. In Uganda both fowl and eggs as well as mutton are prohibited to women only. The Samoans eat dogs, but despise eggs and chickens. Similarly, the Witoto of Brazil, described as omnivorous, eating as they do rats, mice, frogs, lizards, snakes and turtles, eat the eggs of reptiles but despise those of birds. The Iroquois of New York indulged in eggs of many species of birds, but unlike us consumed them in a state just prior to hatching. The Ashanti who, as we have seen, do not taboo eggs except to girls before puberty, impose the death penalty upon any one who accidentally drops an egg to the ground and breaks it. We have mentioned that one reason given for not eating eggs was their being considered the hen's feces. Other tribes give other reasons such as their having "a weakening effect upon the organs of generation."

Fish, too, did not escape the trap of human fancy and speculation, and the Egyptians were not alone in viewing it as impure. "The Machinga are looked down upon by some other tribes because they eat fish which the Angoni, *e.g.*, never touch," writes A. Werner. Human beings everywhere react with contempt for those who eat a food forbidden to them. Generally speaking, the pastoral peoples of Africa do not eat fish, "nor indeed may they have it in their kraals: all people who drink milk abstain from eating fish and touching it."

The blacklisting of fish as food is far from being limited to Africa, and unlike other prohibitions seems to have originated independently in several continents. The North American Crow Indians of the Plains "practice no agriculture except to cultivate a little tobacco each year for ceremonial purposes. They make little or no use of the fish which abound in the rivers. The women gather wild fruits and berries, collect edible plants and dig wild turnips and other roots. But the people subsist mainly on the products of the chase and lead the life of nomadic hunters." Fish is included under the item of meat so far as the Hindus are concerned and is prohibited to the sacred castes, a classification different from the one accepted by the Catholic Church. We have seen that the Bible, too, prohibited a large number of fish species. Even the Eskimos "never collect shellfish along the shore: they eat them only when they find them in the storage paunch of a slain walrus." Even the Tasmanians, stigmatized as the most primitive or backward human group, had their food taboos, the major one of which was fish. Primitive

they very well might have been, yet they "would rather starve than eat fish," one author reports. In addition, the very act of fishing, like most of man's ways of obtaining an essential food, was subject to specific rules. For example, the agricultural Ganda of Uganda on the shores of Lake Victoria indulge in fishing on a large scale. In this they seek the aid of magic medicines obtained from the priests and offer in return a portion of the catch to the temples, their gods and priests. Moreover, while the traps are set, the fishermen and their families abstain from meat, salt, from relations with their wives and from any acts of courtship.

Generally speaking, meat carries the brunt of the burden of tabooed foods in an almost endless variety of ways. The Eskimo, for example, evolved the most intricate set of taboos serving to segregate all activities centering around sea mammals from those related to the deer. Not only the consumption of their meats but all tools and functions concerning them had to be kept strictly apart. Characteristic of the extension of a taboo is the custom which sprang up in some communities of not permitting a dog to gnaw the bones of a deer when the seal-hunting season was on and *vice versa.* In addition boys and girls before puberty are forbidden the meat of "narwhal, young seals, all small animals, viscera and eggs." The Hottentots proscribe the flesh of all carnivorous animals and the hare to men only. Of course, many sects of Hinduism, Buddhism and some Catholic orders eliminate all meat from the diet of their followers.

On the positive side of the meat ledger we often find a laxity which does not impress us very favorably. Thus most Bantu tribes consider mice and rats a great delicacy, naming it "ndiwo" or relish. Even here prohibition enters. Often, as among the Achikunda, "rats are forbidden to women and to those who offer sacrifice." They are usually eaten roasted. Grasshoppers and worms were widely considered a great delicacy, as were ants and gnats. The truth of the matter is that there are few animals that were not eaten by some group at some time. Often as in the case of the hippopotamus some tribes get their living by eating it while neighboring ones consider that animal sacred. Still others view eating it about as disgusting as we regard eating rats. A rather unique article of diet are body lice, considered a "particular delicacy" by the Witoto of Brazil already referred to, as well as the Hottentots of Africa. The Eskimo also breed an ample stock of lice in their furry dress and with their peculiar cleverness invented a special instrument for gathering them as food. With them eating lice assumes as well a romantic glamor. When a young lady decides to accept a persistent suitor she combs his hair and eats the captured prey. This is a sign to all that her mind is made up and her future husband chosen.

Of special significance are food taboos involving the various sexual stages of women. Many are the cultures that evolved a double dietary standard which imposes special restrictions on women generally, rarely on men. We have already cited several restrictions affecting the period before puberty. Aranda boys, for example, may not eat lizards and pure fat lest they become deformed. Girls, on the other hand, are forbidden to eat echidna, eagle-hawk and brush turkey because these foods are detrimental to the development of breasts. During the period set aside for puberty rites girls, and often boys as well, were subjected to virtual fasting or to prolonged starvation or to special dietary prohibitions which were of course mild by comparison with the physical torture they often had to endure. The widespread nature of these customs which

appear in North and South America, Africa, Australasia and Australia is particularly striking.

Special food taboos for women during their periods of menstruation are equally common. The peak in dietary restrictions is reached, however, in the rules pertaining to the state of pregnancy. These are as ubiquitous as the very phenomenon of dietary regulations. The pregnant Aranda woman denies herself numerous items of food lest it harm the child. The Malayan Semang abstains from large fish, pheasants, monkeys, squirrels or any animal killed with bow and arrow. For some reason the pregnant woman's father often submits to the same taboos. A pregnant Ainu woman may not eat fish or lobster, nor may she do any spinning, while among the Incas of Peru, the husband observed the same dietary restrictions as his pregnant wife. An Iroquois wife abstains from all meat during gestation and eats nothing but fruit and small fish during the last month. These restrictions are encountered all over the earth.

Special prohibitions are also set aside for the nursing mother. These vary from place to place but are strictly adhered to for fear of harming the child. Among the Witoto it reaches a peculiar expression. After delivery, for which process primitive women usually interrupt their daily routine only for a matter of several hours, the Witoto woman presents the baby to the father, who goes to bed with it and observes all dietary rules. These are usually abstentions from meat and with the Witoto involves also not touching his weapon. This custom of the couvade is intended to deceive those who would envy the woman her child, and cast an evil eye.

Mourning ritual more often than not also demands dietary abnegation, as does even mere contact with death. Samoans, like the Incas, must fast four days, after touching a corpse or an object belonging to it. The Dahomeans, on the other hand, fast only three days and abstain from washing. While some tribes, like the Todas of Southern India, merely observe many food taboos on the occasion of death in the family, others like the Eskimos require of all who come in contact with the deceased to remain indoors, avoid all work, keep clothes on night and day, and eat from separate utensils. Mention should also be made of the great destruction of wealth indulged in at death. Not only are wives immolated at their husband's funeral, but large numbers of slaves and vast amounts of property are freely destroyed or buried. The corpse is often loaded with food on his journey into postulated worlds, to feed his rotting body or bribe imaginary guardians along the long road.

Another human element which exerts a mighty influence upon the biological process of feeding is prestige. There is more truth than meets the eye in Lowie's assertion than man is more of a peacock than either an economic or biologic animal. While it is true that man must eat it is also true that he will fast and destroy much precious and hard-earned food, to say nothing of his inflicting inconceivable torture upon himself, when the quest for prestige dictates. "The lack of purely economic points of view is everywhere visible in the life of primitive peoples. On various occasions valuable food-stuffs and stocks of all kinds are destroyed, burned, or thrown away from motives connected with religion or witchcraft," writes R. Thurnwald. The author further adds, "All observation of primitive peoples teaches us that the social motive, the desire for an exceptional position in the group has outweighed the economic motive." The Trobriand Islanders, as observed by Malinowski, afford a relevant illustration. The natives build their yam houses so that their contents can be seen. Extra large yams are framed, painted, deco-

rated, hung outside for display and left to rot. Their owners will seek wild fruits and roots in the forest rather than eat the yams needed for display. In fact the right to display yams at all is a great privilege of the upper class, and poor people must cover the front of their yam houses and fatten on their contents.

A similar example is supplied by the well-known institution of the potlatch. Prestige among the wealthy Kwakiutl Indians is obtained by throwing a party to display one's ability to burn food and blankets, destroy canoes, kill slaves and melt most precious and highly valued decorated pieces of copper. "Furthermore, such is my pride, that I will kill on this fire my copper Dandalayn which is groaning in my house. You all know how much I paid for it. I bought it for four thousand blankets. Now I will break it in order to vanquish my rival. I will make my house a fighting place for you, my tribe. Be happy, chiefs, this is the first time that so great a potlatch has been given." Words like these cause the hearts of all tribesmen to swell with pride. If the invited chiefs who come properly prepared can not match the quantities destroyed by the host they are defeated and lose status.

It should also be mentioned that there are very few cultures which do not indulge in some narcotic, in the form of smoke, bitter or inebriating drink or some drug. Fermenting juices are virtually as old as man and are obtained from whatever staple food happens to prevail. The Aranda chew pituri, the Kirghiz Kazaks of Central Asia drink fermented mare's milk known as kumiss and eat and smoke opium. The Iroquois brew various "teas," chew barks and ferment honey. The Hottentots smoke narcotic herbs, hemp and hashish. The Witoto chew a coca preparation containing cocaine.

The following is typical: The author of the quotation, E. Torday, traveled on a steamer plying Lake Victoria and carrying a load of hemp.

Hemp smoking is a widely spread and promiscuous practice. In the interests of their health, I intervened, purchased the whole supply and deposited it in the fire. They came to remonstrate and when I tried to explain how bad it was for their health to smoke it they would not believe me; in fact, one man told me that hemp was food, strength and happiness for them and that without it life was not worth living.

We are all familiar with the nineteenth century picture of primitive man who brutelike follows the direct call of his instincts and biological urges. When he hears the call of hunger, he seeks food, just as he presumably indulged in sex relations when his appetite was aroused. Consider, however, how a typical Australian, a savage, by all definitions, fares on his quest for food. "No sooner does a boy begin to go about in the bushes in search of food than he finds himself very considerably restricted as to what he may and may not eat. Should he eat kangaroo tail or wild turkey, or its eggs, then he will become prematurely old; parrot or cocatoo flesh will cause the growth of a hollow on top of his head, and of a hole under his chin; large quail and its eggs cause the beard and whiskers not to grow; any part of the eaglehawk, other than the sinewy legs, will produce lameness, though the strong legs are admirable, as they improve the growth of the same limb; in fact to strengthen the limb, boys are often hit on the calf by the legbone of an eaglehawk, strength passing from the one into the other. Should the podargus, or night jar, be eaten then the boy's mouth will acquire a wide gape." It may well seem that modern man, with all his burden of proprieties and civilized niceties, is no less encumbered in the search of food than his savage Australian brother.

The very manner of eating has also been subjected to a wide range of rules. It is very common for men and women not to eat together. In such cases the

men eat first and apart from the women, and often have separate utensils. Such customs prevail in Asia and Africa, in Greenland, Hawaii, Bolivia and Melanesia. In many cultures it is most compromising to be observed by any one in the act of eating. That our sanitary manners at meals are recent acquisitions or that the fork seems like a vulgar tool to many tribes is, of course, common knowledge.

The Reach of Belief-Tentacles

Just as many foods are often prohibited to girls before puberty and women in their various physiological circumstances, so does the custom prevail in lands where circumcision is practiced to permit certain foods to boys only after that ritual had been performed. Often it is the father or mother or both who are forbidden to taste certain items so long as they have an uncircumcised boy in the family.

Occasionally we encounter sumptuary laws best illustrated by the Inca state which bears great similarities to modern ideals of state socialism. The mass of commoners consisting of agricultural and pastoral workers were obliged to produce a surplus for the maintenance of the upper class of nobles, priests and officials. To secure such a surplus the standard of living of the masses was regulated. They could only wear certain coarse clothes and eat specified simple foods. All choice delicacies, stronger intoxicants and coca were prohibited to them and constituted the exclusive right of the aristocracy.

Equally common in regions far apart are food prohibitions affecting only certain classes, not always those of the lower strata. In India meat-eating is reserved for lower castes only. Often chiefs and rulers are subjected to numerous restrictions while the lay and the slaves are permitted delicious food. In fact, it is the consumption of such food that intensifies the contempt in which they are held. For example, the Tuareg nobles taboo and abhor the flesh of the sheep, camel, fish, birds and eggs, all of which are permitted to the common people. Often the privileged medicine men or nobles reserve for themselves the innards and the organs such as kidney, liver, heart or head, leaving steak and muscle for the others.

Food plays a major role in most religious ceremonies and ritual. It is not only offered as sacrifice to the gods but often specific items are reserved for that purpose and may be eaten only ceremoniously. Eating of the totem would come under this heading. As a rule the animal which was the totem of the group was forbidden food except when it was sacrificed about once a year. Its flesh had to be eaten then by every one so as to renew their symbolic union.

Another force affecting eating habits was the prevalent notion that certain organs were the seats of given virtues and their consumption would therefore inevitably strengthen those qualities in the consumer. Similarly, animals and plants famed for some peculiar characteristic were believed to impart their powers to those who ate them. This belief was a major assumption in primitive medicine. With regard to plants it was expressed as the doctrine of signatures implying that the external appearance of each plant indicated its curative powers and functions. Thus the yellow dandelion was believed to cure jaundice and red petals or blood were used to help anemia. Strangely enough, many good guesses were hit upon by this haphazard method. This erroneous theory also contributed to the expansion of cultivated plants used as herbs. No distinction was made between internal and external application and many herbs found their way into the diet as relishes.

All evidence indicated that cannibalism was not the savages' simple recourse

to the satisfaction of hunger, as early anthropologists assumed. Rather was it a ceremonial function, an expression of jubilation and victory. If the enemy was brave his heart was invariably eaten. Under all circumstances a cannibal feast was not an ordinary meal but usually a strictly controlled ritual affair.

Few primitive societies show any planning for the future. Neither do they show any trend toward private ownership of land, hunting grounds or commercialization of food, though no culture without some form of private property has yet been discovered. The statement "A whole village must be without corn before any individual can be obliged to endure starvation" applies beyond the Iroquois for whom it was meant. With primitive man's strong sense of tribal loyalty food is as social a problem as air, water or hunting grounds. The sale of food to members of one's own tribe is as unthinkable as its sale by a mother to her child and *vice versa*. On the other hand, foresight and economy are often completely lacking. Besides in many cultures the remainder of a meal must be destroyed and those who partake of it may be punished or even killed.

In our own culture the belief prevailed until almost recently that remnants of food formed part of the person who partook of that food. Hence, like hair or nail parings they gave their possessor magical power over that person. It was in fear of such magic that nail parings, cut hair and left-over food were meticulously burnt. Only three hundred years ago these beliefs were accepted in our own culture and the possession of food remnants or nail parings of another person was used as sufficient evidence to condemn thousands during the witchcraft persecution of the Middle Ages. The fact that such men as Francis Bacon and Robert Boyle shared these beliefs should make us pause and think before we ridicule or "explain" the beliefs or, as we prefer it, the superstitions of other cultures.

Conclusions

We may briefly summarize the meaning of the material here presented. To begin with, the simple-minded formulation of man's food problem which for convenience we may designate as mechanistic must be uncompromisingly destroyed. While man does have to eat in order to survive there are numerous factors linked with that process giving it a multitude of expressions.

To understand man one must know not only our provincial society but the expansive horizons of man's variegated past and present. It is then observed that fundamentally man is very much the same to-day as he was many thousand years ago, though the external aspects of his particular institutions and conduct may have undergone large changes. In different cultures, at different times he maintained different assumptions, beliefs, values, institutions and practices. Yet, all the differences we note are fundamentally peripheral in nature.

Man attempted to explain death or thunder and strove to cure disease then as to-day. An expectant mother sought to do well by her growing child then as much as to-day. And primitive man acted on the basis of his aims and assumptions in precisely the same manner as we do to-day except that his aims and assumptions often differed from ours.

The biologically harmful and seemingly irrational food habits of most human cultures must not blind us in our judgment of man. In fact, our very reaction to these habits is in itself an excellent lesson in human nature and conduct. On becoming acquainted with their strange semblance, we immediately designate them as irrational because they differ so much from our own. Since we

consider our own as natural because we have come to regard them as part of the course of nature, we also consider them rational. It then follows that contrary ones must be classified as irrational.

We still lack training in scanning true human perspectives, in overcoming narrowness, emotionalism, and provincialism. In a word, we have not yet mastered a truly scientific approach to man. We fail to see that man is indeed a peculiar animal. He is and always has been capable of great nobility and generosity but also of great selfishness and cruelty. He is capable of great kindness and sacrifice but also of great prejudice and hate. He is a great innovator, a most ingenious discoverer, but can also for centuries persist in harmful habits or beliefs, and even resist with intricate logic any efforts at change. He is both master and slave.

He behaves very much the same in matters of diet which, in the long run, are as much related to biology as any other elements of his culture pattern. Ultimately, all social institutions are closely linked with welfare, satisfaction and survival. And so in matters of food too, man, primitive as well as modern, has displayed amazing courage and ingenuity. Here, too, he gave free rein to his trend to regard the habitual as the natural and to let his customs become part of his culture pattern, his web of belief and practice.

Little need we wonder at the fact that practically all religions came to include dietary notions and regulations. Religion, as A. Eustace Haydon so eloquently stresses, is a way of life. Contrary to the notions of most scientists of the last century, religion is not fear, ignorance or naivete but an integrated summary of the customs, beliefs, values, hopes, explanations and aspirations of each human group. As such, it naturally sanctions those aspects which are accepted and regarded by the group as natural or proper. But it also gives expression to man's quest for a better life, for a world juster than the one that has him in its clutches, for a life in which his innate values of justice, kindness and brotherhood prevail. Since dietary practices, as we have seen, are part and parcel of man's customs, beliefs and rationalizations, part of his institutions as well as his concepts of right and wrong, it was inevitable that they find a niche, often as in India a very spacious and influential one, in his religious lore.

In his quest for food primitive man showed amazing inventiveness and ingenuity, witness the manioc culture of the Witoto, the plantain of Uganda or the agave of Mexico. In the inclement regions of the icy north, in sandy deserts and rocky lands he managed through fantastic adjustments to secure a livelihood and enjoy a fairly well-balanced vitamin diet. With few exceptions his staple food was a vegetable, though, as we have seen, it could also be milk or meat. What is amazing is that in the absence of vitamin knowledge he usually succeeded quite unconsciously to vary his diet sufficiently so as to satisfy all protective requirements. That he is not urged to do so by an inner drive as are many animals is quite clear by the number of cases where he goes wrong. But that he succeeds at all, on an exclusive meat, milk or vegetable diet with often fantastic prohibitions and regulations is indeed a wonder.

As an illustration of an ingenious adjustment manioc may be selected. Its starchy matter is eaten by many South American tribes who originally used it as a source of cyanide poison for their arrows or for the poisoning of lakes or pools during a fish hunt. The fish would become narcotized or would die, rise to the surface and be gathered in with ease. In the course of time it was discovered that what was left over after the extraction of the poison could be converted into an edible bread-like staple. Now,

contrary to the original practice, it is being used as food and its poison is discarded. The plant is ground and washed until all the poisonous compound is dissolved and the residue is used like flour.

Yet primitive man's choice of diet is no more "rational" or scientific in our sense of the word than biological mutations are purposive. Primitive man follows his emotions and reasoning in a thoroughly human manner. What we call magic was his science. Conversely, what many modern, popular writers on food call science is merely the mechanistic magic and superstition of our day, seeking to explain away rather than study fundamental phenomena.

While our knowledge of metabolism, digestion and vitamins has expanded and modified our reasoning on the subject of diet, we have as yet neglected the study of many emotional forces still governing dietary notions. It is a fact that we tend to rationalize our own dietary taboos, such as those against horsemeat, rats or earthworms. The very act of seeing some one eat such tabooed food affects us unpleasantly. It is also a fact that a dietary habit once established is extremely difficult to break. A Hindu friend who had long since abandoned most of his faith took six years to finally eat fish but after ten years' sojourn in London could not muster enough strength to eat beef. Mohammedans who as adults become converts to Christianity or Atheism seldom learn to eat pork or to control their nausea at seeing others eating it.

The kind of food as well as its preparation and eating etiquette tend to become standardized in and characteristic for each culture group, as do all other culture elements. Once established they are modified slowly and with great difficulty. Like language, dress or religion, a diet becomes part of a rational and emotional belief pattern, which in turn exerts a mighty grip on the community. Changes in diet by diffusion or by inner mutation do at all times occur, but they are slow, haphazard, uncontrolled and unpredictable. And the sad fate of the buffalo-hunting Plains Indians who would not and could not become agricultural is a worthy lesson. To weaken consciously the grip of an evil belief and replace it by desirable scientific habits is therefore a stimulating challenge to the social scientist of to-day.

The introduction of scientifically sound food habits into the people of our country requires much study of the type of material here presented and of its varied implications. To know how bad food habits can be displaced and good ones introduced, one has to understand the intricacies of the psychological forces that interplay with the urge to eat. Biology and economics constitute only two variables of this complex equation. Obviously there are more factors and weighty ones at that. People do not develop a taste for oysters on being informed of their excellent dietary worth. Nor do they abandon alcohol, tobacco or a favorite dish on being lectured about their dietary insufficiency. To change bad food habits of a community and put them upon a scientific foundation, more than the biochemistry of nutrition is needed. One must learn to understand custom and cultures and their psychological matrix. One must learn ways and means of loosening old bonds and of introducing new ones.

DOES HISTORY SHOW LONG-TIME TRENDS?

By PAUL B. HORTON
DEPARTMENT OF SOCIOLOGY, DUKE UNIVERSITY

ARE there long-time trends in culture—broad general movements whose sweep transcends the rise and fall of individual civilizations? The question seems highly pertinent, among other reasons, because of its significance for prediction and control of human affairs. Prediction is based upon the assumption that some patterns of the future bear a discoverable relation to patterns of the past, and intelligent control presupposes an understanding of the manner in which the phenomena operate. If social science is to predict and control—the latter point being one on which not all social scientists agree—the demonstration of cultural trends which have already survived the rise and fall of several civilizations would simplify the problem by providing some probable tendencies around which to orientate predictions and frame controls.

Recent reactions against the social optimism of the eighteenth and nineteenth centuries[1] seem to have reached the point of denying, directly or by implication, the existence of such a thing as social progress or even an orderly succession of generically related events. Ruth Benedict writes:

> Anthropological criticism has been leveled for a long time against the whole assumption that the course of civilization can be made to fit into any rational scheme. The history of the human race is irrational to the point of melodrama. It can be made to conform to "law" only by lopping off everything that will not fit.[2]

Radin maintains that the evolutionary theory of successive stages ". . . has today quite outlived its usefulness and . . . those of its postulates that are still a living force are more harmful than beneficial to ethnology."[3] Goldenweiser claims that

> No anthropologist today believes in an orderly and fixed progression of cultural events. . . . Equally obsolete is the concept of gradual transformation (by "imperceptible gradations"). . . . For no anthropologist believes that any large part of culture is invented, that is, represents the culmination of a process of rational thought.[4] The role of emotional and unconscious factors may not be wholly understood, but all accede that most of what we call culture comes from this source.[5]

Sorokin, firmly convinced that the ". . . progress cult is already out of date . . ."[6] denies at least twenty-one times in his recent work ". . . the existence of a perpetual main linear trend in history and most of the social processes."[7]

[1] The eighteenth century social optimism so eloquently stated by Condorcet and Turgot affirmed a profound faith in the inevitability of social progress, asserting that except for temporary reversals, all social change was in an "upward" direction. Spencer popularized "social evolutionism" with its attempt to classify all cultural variations into a series of predetermined categories, which were then assumed to be the successive stages of an evolutionary sequence.

[2] Ruth Benedict reviewing Robert H. Lowie's "Are We Civilized?" in *New York Herald Tribune Books*, September 15, 1929, p. 4. (Abridged and quoted by Hornell Hart, "The Technique of Social Progress," Holt, New York, 1931, p. 20.)

[3] Paul Radin, "Social Anthropology," McGraw-Hill, New York, 1932, p. 11.

[4] Goldenweiser inserts a footnote excepting mechanical invention.

[5] Alexander Goldenweiser, *American Journal of Sociology*, 31: 19–38.

[6] Pitirim A. Sorokin, "Social and Cultural Dynamics," American Book Company, New York, 1937, Vol. III, p. 535.

[7] *Id.*, Vol. I, p. 187. (See "linear trend; lack of" in indices.)

Statements such as these create an impression of culture as growing almost entirely through accidental accretions, fluctuating aimlessly within some possible limits of variability, and showing no long-time trends or rational tendencies. Buried in the footnotes one may find concessions as to the existence of trends in mechanical invention, in the growth of knowledge, and in man's ability to cope with his physical environment. Yet if the comprehensiveness of treatment of a topic bears any relation to its importance, it may be assumed that these conceded trends are not considered very significant aspects of culture. Since the question of just which are the more significant aspects of culture is open to debate, it should be entirely relevant to suggest several apparent long-time trends whose implications may be somewhat more important than much of the anthropological literature would seem to indicate.

1

Possibly the most obvious long-time trend is found in the *increasing breadth and precision of man's knowledge of the physical universe.* The progressive accumulation and integration of facts and the elimination of fallacies has proceeded in practically every field of knowledge (with the exception of a few of the more esoteric branches and specialized arts). Although this process has been neither uniform, steady, nor consistent, each great civilization has forged onward towards new discoveries in at least some of the fields of knowledge, while preserving much of the learning of the past. An example outside the field of industrial arts is that of astronomy: The Egyptians orientated their pyramids to the heavens, and the Babylonians were predicting eclipses as early as 3800 B.C.; the Greek astronomers, Aristyllus and Timocharis, in the third century B.C., constructed the first catalog giving star positions as measured from a reference point in the heavens; Ibn Junis compiled the Hakimite Tables of the planets and was the first to record solar eclipses with scientific accuracy in 977–8 A.D.; Copernicus remade astronomy in the sixteenth century, and the astronomical discoveries of the present "great" civilization are still appearing.

If one traces, as it is passed from one civilization to another, the history of some of the industrial arts, such as glass making[8] or metal working,[9] the story of their development is an even more striking illustration of the successive contributions of diverse cultures. Even though much knowledge has been lost and many arts forgotten, it is obvious that the sum total has been increasing. The mass of knowledge of each civilization consists of its particular contributions plus what it preserves from its heritage. History and anthropology are made possible by the fact that some of the lore and the artifacts of the ancients have survived to form part of present knowledge; otherwise reference to the past would be impossible, and any who would refute the growth of knowledge by comparisons with the wisdom of the ancients overlook the fact that such comparison is possible only because this ancient lore still survives,[10] and is to-day supplemented by modern increments to a total which makes such comparisons futile. The accumulation of millenniums of experience, recouping the losses of successive reversals, now gives man the power to peer a billion light years out into space and see cosmic drama as it transpired a billion years ago,[11] or to

[8] See Frances Rogers and Alice Beard, "5000 Years of Glass," Stokes, New York, 1937.

[9] See T. A. Rickard, "Man and Metals," Whittlesey House, New York, 1932.

[10] For this observation the writer is indebted to a conversation with Dr. Howard E. Jensen.

[11] See *New York Times Magazine*, September 4, 1938, p. 7 plus, for a discussion of the anticipated powers of the 200-inch telescope nearing completion at Palomar.

peer through a microscope and break a pin-point into a thousand fragments; to analyze with a spectroscope the chemical composition of Arcturus, and halt with stroboscope and camera a bullet in its flight. The subdivision of knowledge and investigation into an increasing number of specialized fields is a recognition that the mass of knowledge within a field has become too vast for one man to assimilate, or the possibilities of research too ramified for one man adequately to consider.

2

This first trend has been accompanied by *increasing accuracy and efficiency in recording and diffusing this knowledge of the physical universe.* Since the day when man first began scratching pictographic ideographs on his cave walls some 25,000 or more years ago, he has been refining his methods of recording and diffusing ideas. His development of the phonetic alphabet, probably in the Sinai peninsula, was fairly complete about 4000 years ago, and of Arabic numerals roughly 3000 years later. For about 3000 years libraries have served as growing storehouses for his information. Two thousand years of development of indexes of all sorts—encyclopaedias, gazetteers, concordances, glossaries, dictionaries—dates from the earliest known encyclopaedia, Pliny's thirty-seven volume *Natural History,* written nearly 1900 years ago; to-day, libraries, indexing, and cross-referencing open at a moment's notice the door to records of man's vast experience. The speed and accuracy with which man can preserve and transmit his ideas has been increasing at an accelerating rate as inventors have given him shorthand,[12] lead pencil and fountain pen, durable paper and permanent inks, printing press, typewriter, linotype, teletype, phonograph, radio, dictaphone, photography, motion picture, microphotography,[13] telephoto, television, and important techniques of restoring and preserving manuscripts.[14]

3

Even those who do not believe in trends recognize man's *increasing ability to* MANIPULATE *his physical environment.* An explanation for this trend is found in the accelerating frequency of invention and discovery. Darmstaedter traces the frequency of invention and discovery over 5500 years, with a low point of 22 during the 2700-year period from 3500 to 800 B.C., an increase to 61 during the first century A.D., a decline to four per century during the fifth and sixth centuries, then another quite consistent increase, rapidly accelerating during the latter centuries, to a high point of 2880 for the last quarter of the nineteenth century.[15] It is highly probable that the paucity of ancient invention and discovery and the violence of the fluctuations is somewhat exaggerated by the inadequacy of the records.[16] Even so, a rapid

[12] Used at least as early as Greek and Roman times. (See *Encyclopaedia Britannica,* "Shorthand.")

[13] See M. H. Savelle, *Library Journal,* 60: 873–8, Nov. 15, 1935; M. L. Randy, "Microphotography for Libraries," American Library Association, Chicago, 1938.

[14] See F. Jacobs, *Scientific American,* 155: 260–1, November, 1936; J. Grant, "Books and Documents; Dating, Permanence, and Preservation," Grafton, London, 1937.

[15] Pitirim A. Sorokin, *op. cit.,* Vol. II, pp. 134–5.

[16] Conclusions concerning early inventions must be based upon the fragmentary evidence offered by the comparatively few ancient manuscripts and artifacts which have survived the centuries, further limited by a "history" which only recently has considered that civil life and technology approach battles and dynasties in historical importance. Common in ancient and medieval times was a cultural ethos in which problems of production were matters for slaves and the poorly-born to wrestle, while philosophy, statesmanship, war, and court life were the proper interests of the gentlemen; thus the educated classes were disposed neither to invent, nor to extoll the inventions of their "inferiors." It is likely that more than one invention was devised, applied, outmoded, and forgotten, leaving no trace for the modern student to discover.

acceleration in the rate of invention and discovery seems an inescapable fact. Indeed it is to be expected from the very nature of the inventive process. Every invention consists in new combinations of old elements, materials, and ideas; therefore, as the number of inventions increases, the possible number of new combinations and applications increases in something like a geometric ratio, and new discoveries usually introduce still further fields of research. It is quite true that many modern inventions are of little consequence as compared with, for example, fire-making or the wheel-and-axle; yet it will hardly be denied that the application of new inventions and discoveries changes living habits and technology far more rapidly to-day than in any previous era.

Further evidence of man's growing ability to cope with his physical environment is found in the trends of production of goods and scales of living. It requires no involved research to conclude that modern levels of production are far higher than ever before, nor does it require a logician to deduce a causative relationship between the trend of invention and discovery and the trend of production. Within recent decades famines have disappeared from that part of the world in which modern methods of agriculture, industry, and transportation have become dominant. For the first time in history, man has it completely within his power to banish famine and pestilence from the earth, a realization which needs await only a peaceful world and a wider diffusion of present knowledge.

A more recent aspect of man's conquest of his environment appears in a flood of synthetic products, alloys, plastics, and new technical processes. Chemists report that instead of being dependent upon a single raw material for a particular product, a growing variety of essential products is now becoming available from several different raw material sources.[17] This is especially true with the coal-tar and petroleum products, most of which can be derived from either source, and the plastics industry, in which almost any basket of vegetables can be turned into radio cabinets and door knobs. The history of technology is showing an expanding variety of material devices, an increasing variety of sources from which a given product or material can be derived, and a growing variety of products or materials through which a given function can be discharged or a given need satisfied.[18] An important effect of this process is to reduce dependence upon any one source, material, or product,—to reduce a society's *vulnerability to economic dislocation* through increasing the technological adaptability; thus the "survival power" of a society is augmented, in so far as problems of economic production are concerned.

4

A fourth long-time trend is found in *the expanding units of cultural interaction*, both cooperative and antagonistic. One aspect of this trend appears in the increasing *size* of political units, from the primitive tribe to the modern empire or commonwealth. With two exceptions (Assyrian and Roman), each "largest" empire in history probably has exceeded all its predecessors in land area,—Early Egyptian, Late Egyptian, Assyrian, Persian, Roman, the Caliphate, the Empire

[17] See William A. Hamor, *Industrial and Engineering Chemistry, News Edition,* 16: 1 plus, January 10, 1938; G. J. Esselen, *Industrial and Engineering Chemistry,* 30: 125–30, February, 1938.

[18] *E.g.,* For lighting, heating and cooking purposes:—To fats, wood, and vegetable fibers have been added coal, natural gas, coal gas, gasoline, kerosene and other petroleum and coal-tar products, alcohol, and electricity. Gasoline and kerosene can be derived from at least two sources, alcohol from at least a hundred, and electricity from chemical action, mechanical power, or combustion of any fuel.

of Ghengis Kahn, and the British Commonwealth of Nations. As the size of political units has expanded, the scope of such activities as warfare has increased similarly. While the *frequency* of wars seems to show neither a consistent increase nor decrease,[19] the *magnitude* of wars has kept pace with the size of the units which wage them, and the *proportion of casualties* has mounted as military devices have become more efficient.[20]

The unit of economic activity has expanded in a similar fashion. Among the primitives, the household, clan, or tribe was an almost completely self-contained and self-sufficient economic unit; to-day the world is an economic unit, with every nation vitally dependent upon economic imports from other nations. The unit of production has shifted through the centuries from the household, clan, or tribe, through the small shop to the large factory or chain of factories; the unit of distribution from the household, clan, or tribe, through the region and empire, until the entire world is now the distributive area for a growing variety of products.[21]

5

A fifth long-time trend, of which contemporary politicians are vociferously aware, is the *expansion of the function of the state*. In addition to such entirely new governmental functions as may appear in a changing world, a great many functions formerly performed by the family or other social groups have gradually been assumed by the state. Anthropologists, studying those peoples whose primitive way of life has survived until modern times and can therefore be studied directly, have found that wherever primitives have lived in very small, isolated groups, such as the Eskimos, Tasmanians, or Semang, nothing resembling a formal government, not even a chief, could be found;[22] among those peoples who lived in larger groups, political organization tended to become more complex, until the governments of the Inca, Aztec, Ganda, and Dahomean nations rivaled their European contemporaries in complexity of structure and function.[23] Anthropologists have found that among the small groups of simpler peoples, redress of wrongs was the function of the individual or kinship group, and order maintained largely through the informal social controls of ridicule and ostracism. Among the larger groups with a more complex material culture such functions as group defense, punishment of crime, and maintenance of order were withdrawn from the individual or kinship group to become the functions of formal governmental authority.[24] It is a logical assumption that this has been an historical process—that the relationship between the size of the group, the complexity of material culture, and the complexity of political organization and function is historically, as well as immediately valid. As the size of human

[19] Pitirim A. Sorokin, *op. cit.*, Vol. III, p. 347.

[20] *Id.*, p. 337 (see also footnote 28).

[21] The recent intensification of economic nationalism and the recurrent discussion of international federation represent two conflicting ideologies, one of which would reverse and the other extend this trend towards larger units of economic activity. It is also possible that scientific development may reverse this trend by making utilization of distant sources of supply less necessary.

[22] George P. Murdock, "Our Primitive Contemporaries," Macmillan, New York, 1936, pp. 1–19, 85–106, 192–220.

[23] *Id.*, pp. 259–402, 403–50, 508–550.

[24] See L. T. Hobhouse, G. C. Wheeler, and M. Ginsberg, "The Material Culture and Social Institutions of the Simpler Peoples," Chapman and Hall's, London, 1930, Ch. II, pp. 46–141. See especially p. 82: ". . . the development of social order is roughly correlated with advance in economic culture. The lowest societies are very small, and even within the smallest groups there is very often no provision for the maintenance of justice. As we advance . . . we get always larger societies, and by degrees provision for the maintenance of justice."

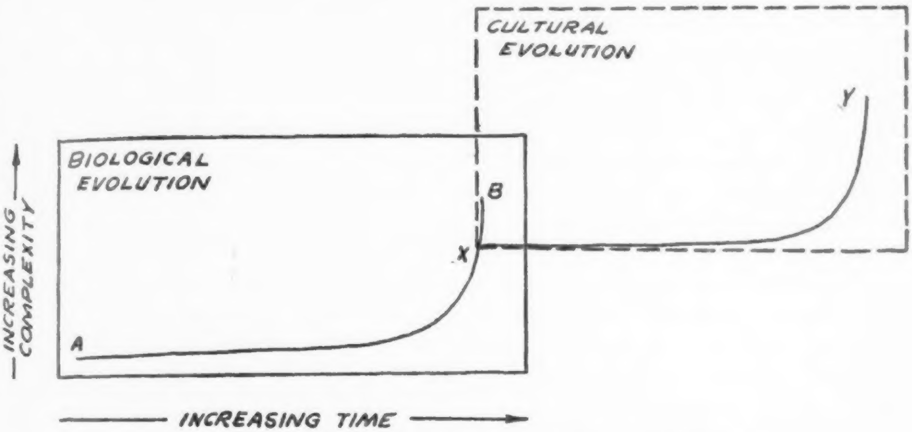
groups has increased, as empires have grown, more and more functions have been assumed by governmental authority—another way of saying that increasingly complex societies have been confronted with an array of constantly more involved problems, for whose collective solution governments have developed. In recent decades this process, like many others, has proceeded at an accelerating tempo, with such functions as education, care of defectives and dependents, and considerable regulation of economic affairs becoming state functions,[25] and indications seem to point towards the continuing functional expansion of the state.

It is quite evident to all careful students that by no means does *all* of human history fit into any series of logically-developing trends, but this admission certainly does not preclude the possibility of there being certain sections of historical phenomena in which trends may appear. In fact, the case for the existence of some trends becomes even more convincing when it is noted that the five trends suggested in this discussion are, to a very considerable extent, mutually dependent and inter-related; *e.g.*, the assumption of more extensive functions by the state is intrinsically related to the growth of scientific knowledge, its preservation and communication, man's control of his physical environment, and the size of the units of cultural interaction.

That there have been violent fluctuations within all of five suggested trends is unquestioned; that they all constitute long-time trends seems inescapable. Possibly the term, "long-time trend," should be defined. "Trend" is defined in Webster's dictionary as an "underlying or prevailing tendency or inclination; general direction taken by something subject to change;" hence even a conservative use of the term would admit that in a diagrammatic representation of a long-time trend, fluctuations of lesser magnitude than the vertical distance between the extremities of the trend line would not invalidate the trend. Now it is quite obvious that all of man's culture—his tools and structures, his technology, his ideas, his habits, ideals and values—have proceeded from crude and simple beginnings to complex forms. This might be termed "the trend of culture," in analogy to the "trend of biological evolution." If biological evolution has proceeded as generally believed by biologists, the course of biological evolution might be represented diagrammatically by a curved line "A–B," with "A" as the beginning of unicellular life, and "B" as the present stage of biological evolutionary development of man. One-celled life, however, possessed no culture; a certain degree of biological evolution is prerequisite to the appearance and transmission of culture. Some degree of intellectual development is necessary before either imitation or tuition of even the simplest adaptations can operate, and at all times the stage of biological evolution sets amorphous upper limits to the possible development of culture. Now, at some point, "X," along the course of biological evolution (without here attempting to determine just were this point should be located), culture must have experienced its penumbral generation. Then, superimposing another diagram with its axes at point "X," the accelerating curve of cultural evolution proceeds to point "Y," the present level of accumulation and complexity of culture.[26] The actual

[25] It should be observed that state regulation of economic affairs is not at all new; in the seventeenth and eighteenth centuries, especially in France under Colbert, such regulation possibly exceeded that at present, yet the *total* functions of the state were certainly far less inclusive.

[26] This diagram should not be interpreted as an attempt to represent "progress" or "improvement," but as an attempt to represent the accumulation and growing complexity of culture. The extent to which these processes may constitute "progress" is a matter for separate consideration.



BIOLOGICAL AND CULTURAL EVOLUTION CURVES

proportions of the curves are not quantitatively determined, nor are the fluctuations indicated; neither is any simple analogy intended. This is rather a diagrammatic representation of the thesis that both biological and cultural evolution have proceeded from simple beginnings to complex forms, and that the present level of culture is more complex than at any earlier period; nor could the curve of cultural development have dropped below point "X," for that point is by definition representative of the simplest possible level of culture. Therefore, despite any fluctuations which would be at all consistent with anthropological evidence, the course described between points X and Y can be nothing other than a long-time trend from simpler to more complex forms.[27]

It can hardly be denied that these several trends constitute important determinants of culture, yet in much of the literature of social science the discussions of long-time trends and their implications are conspicuous by their comparative absence. The modern reaction against "evolutionism" and "progressivism" in demonstrating, for example, that there is no consistent and universal sequence of evolutionary stages from promiscuity to monogamy, from anarchy to democracy, or from a hunting economy through pastoral nomadism to an agricultural economy, has at times tended towards the opposite error of implying that there are not any evolutionary sequences whatever in cultural history. Sorokin avoids discovering any trends among his volumes of statistics by following a simple formula—if there are any *fluctuations,* then there is no trend.[28]

[27] There may be some elements of culture where the tendency has been to move from more complex to less complex forms, as appears probable in the case of religion, for example. Yet such examples do not invalidate the contention that accumulation and growing complexity seem to be far more typical of cultural history than progressive simplification.

[28] In Vol. III, p. 337, of "Social and Cultural Dynamics," Dr. Sorokin presents the following table of data concerning casualty rates in warfare.

PERCENTAGE OF CASUALTIES IN FOUR COUNTRIES FROM THE TWELFTH TO THE TWENTIETH CENTURIES

Century	Casualties as per cent. of army's strength
XII	2.5
XIII	2.9
XIV	4.6
XV	5.7
XVI	5.9
XVII	15.7
XVIII	14.6
XIX	16.3
XX	38.9

Dr. Sorokin then concludes a few pages later that "The study discloses a lack of any con-

In attaching the qualifications, "perpetual linear trend,"[29] "definite, steady, eternal trend,"[30] and objecting that even the trend of population increase (together with all other trends) will be eclipsed by ultimate cosmic chaos,[31] he escapes refutation by defining trends out of existence.

Since the cults of evolutionism and progressivism were closely related to each other in historical emergence and ideological content, it is not surprising that their doctrines of universal sequences of evolutionary stages and of the inevitability of progress should meet joint repudiation. It is not quite apparent, however, just why this repudiation should be extended to preclude the possibility of effective social planning—the calculated pursuit of desired social objectives. Hankins characterizes the position of many social scientists quite correctly in announcing that "The celestially guaranteed progress of the whole society toward idealistic goals *has given place to the concept of mere change.*"[32] It may be no accident that those scholars who pen the most devastating attacks upon trends are often the sharpest critics of the idea that social change can be subjected to any rational direction and control. Hankins maintains that

> Instead of being skilfully directed by social engineers, equipped with clear insight into the social process, the social system will continue to evolve. All we can possibly do is to give it slight impulses here and there, for better or for worse.[33]

DeGrange contends that

> To begin with, there is probably not enough reliable information available concerning "society" to make it possible for an "individual" to be intelligent in regard to it.[34]

Sorokin concludes that

> At the present, all such schemes (for the "*forecast and control* of socio-cultural phenomena") remain as much guesswork and gambling as they were in the past. Only in recklessness perhaps does our present planning abound,[35]

but closes his "Social and Cultural Dynamics" with a dramatic *forecast* of the coming "ideational" era.[36]

One wonders if this frame of mind, when translated into popular parlance, is not related to the almost hysterical anxiety which finds expression in a flood of observations such as these:

> Civilization is not merely on the brink of collapse . . . it has already some years ago collapsed.[37]
>
> In these ten years confidence in the stability, yes, even the basis for existence of human society has largely vanished.[38]
>
> Hope in the Wreck of a Dissolving World.[39]
>
> This life which you lead, a voice says to me continually, is in the deepest sense senseless, a repetition of social gestures, somehow hollow; it ties to nothing, it is a part of nothing. It is a dream, and the reality lies elsewhere. . . . I am in search of a living faith in which to believe, and a body of faith to which to belong. I want to help to create, in order to live in a

tinuous trend . . ." (p. 347). He rejects the usual definition of a trend as *general tendency*, requiring that it be *continuous* in order to qualify. He admits that "... all in all, the casualty rates increased faster than the strength of the army . . ." and that "Recent and modern wars have tended to become more devastating in their killing and wounding power" (p. 337), but does not designate these tendencies as trends.

[29] *Id.*, Vol. II, p. 226.

[30] Pitirim A. Sorokin, "Contemporary Sociological Theories," Harpers, New York, 1928, p. 739.

[31] *Id.*

[32] Frank N. Hankins, *American Sociological Review*, 4: 1–15, February, 1939. (Italics mine.)

[33] Frank N. Hankins, *American Sociological Review*, 1: 36, February, 1936.

[34] McQuilken DeGrange, *American Sociological Review*, 4: 118, February, 1939. (Reviewing F. W. Bridgman, *The Intelligent Individual in Society*, Macmillan, New York.)

[35] Pitirim A. Sorokin, *American Sociological Review*, 1: 12–25, February, 1936. (Italics mine.)

[36] *Op. cit.*, Vol. III, pp. 531–9.

[37] Stanley Casson, *Harpers*, 172: 324–31, February, 1936.

[38] Albert Einstein, *New York Times Magazine*, August 20, 1939, p. 2.

[39] Title for a review in *New York Herald Tribune Books*, September 10, 1939, p. 1.

society with which I am intellectually and emotionally reconciled. . . . I am giving publicity to my symptoms only because they are endemic, I believe, to the largest section of western intellectuals.[40]

It is irrelevant to suggest that if the social scientists possess no ability to exercise any rational direction and control over society neither can the less expert laymen hope for any such powers. Accordingly one would have two alternatives; he might hope that society would "continue to evolve" by itself, unconsciously pursuing the ends which we desire, or he could simply resign himself to the impending catastrophe.

In no sense can these attitudes of defeatism and teleological illiteracy be considered as necessary or logical corollaries to the collapse of the cult of inevitable progress. It is conceded that change is not always "upward" and that "progress" has meaning only with reference to some particular set of values or objectives. But why the wide-spread conviction that all human efforts at social planning must be futile and abortive? This ". . . blind alley of defeatism and cynical despair leads only to the inactivity of resignation. Its end product is a neglect of the pressing social problems and tensions of a dynamic society, and the social sciences are reduced to a polite intellectual diversion for the entertainment of the dilettanti."

The question may arise: What implications for prediction and control can be found in the several trends herein outlined? These trends have all transcended the rise and fall of several civilizations with their widely divergent institutions and values. Accordingly, the trends could hardly be simply the accumulations of *accidental* accreations and variations, for it is unlikely that they would *accidentally* accumulate so consistently. Neither is it likely that they can be explained adequately by cultural choices—by selections that are dictated by the attitudes and values dominant within a particular society—for the different societies which these trends have spanned have been quite dissimilar. The explanation of the survival of these trends appears to lie in elements more intrinsic than these factors. Although their survival to date provides no positive guarantee for the future, their antiquity and their accommodation to diverse cultural situations makes the prospects for future continuance something more than a probability. These trends provide some reasonably tenable propositions around which to develop tentative predictions, the indispensable prerequisites to control.

A few examples may clarify this relationship. Consider the well-known trends of population increase, birth rates and death rates. From a study of these trends, predictions as to the future age distribution of the population, the need and demand for old-age relief, the need for teachers and school buildings, the possible expansion of adult education, the probable movement of land values, the expansion of cities and of business areas within cities, the length of life for which public and business buildings should be constructed, and many others may be ventured with greater accuracy. Few chemists share the anxiety of those who anticipate the exhaustion of timber supplies or coal and oil deposits, for the chemist expects that by the time such resources approach exhaustion, the current sources, products, techniques, functions, and uses will have so changed that seldom will any *one* raw material or source of supply be of crucial importance. This increasing technological adaptability seems likely to reduce the economic interdependence of geographic regions, in which case not only will the economic motives for mili-

[40] Dorothy Thompson, ***Story Magazine***, **1936; condensed in** ***The New Current Digest***, **January, 1937, p. 9.**

tary conquest probably diminish, but the possibilities of self-sufficiency will increase, thereby diminishing the present military advantage of the "have" over the "have-not" nations. If and when physical scientists learn how to add and subtract protons and electrons from atoms at will, then a lump of coal or a glass of water will be potentially anything from hydrogen to uranium and the problem of raw materials will have been solved, for whatever man needs can then be made from whatever materials are convenient. The trend of expanding functions of the state suggests for the future of the democracies a growing concern with the problem of reconciling administrative efficiency with democratic limitations upon authority, perhaps a degree of substitution of vote or job motivation for profit motivation as the basis of the economic order, a further decline of individualistic self-reliance, and a growth of either cooperation or parasitism in society.

These few examples may illustrate how cultural trends that have persisted over long periods in diverse milieu and appear very likely to continue in the future may serve as bases for prediction and control. The existence of a few such tendencies whose continued operation, while not a positive certainty, is an exceedingly strong probability, provides focal points around which further predictions may be orientated. These predictions contribute to the problem of control by defining the areas in which controls may need to be exercised if socially-desired objectives are to be attained. This is not to over-simplify the problem of prediction and control, for social scientists confess that absolute precision in prediction will probably never be realized, nor completely effective controls devised. The purpose of this paper is rather to suggest some long-time trends in human history whose significance may not always be fully appreciated, to show how their recognition can aid in intelligent social planning, and thereby to refute the pessimism and defeatism which asserts that man is incapable of bringing society into greater harmony with socially-desired objectives and values.

SCIENTISTS AND TECHNOLOGISTS IN THE WAR PROGRAM

WHERE do we stand in regard to the various elements which make scientific power effective? These are the ingenuity of our inventors, engineers and chemists; the control of the necessary raw materials; productive capacity; and lastly the ability to use aright the weapons when they have been produced.

It is difficult to exaggerate the importance of the chemist, the engineer and the inventor. The "back room boys," as they have been called, have a part second to none to play.

By land, sea and air the "back room boys" are working all the time to go one better than the Germans. To their researches we owe the great advances made in radio location, by which our anti-aircraft guns and night fighters are enabled to find their targets; to them we owe the antidote to Hitler's "secret weapon," the magnetic mine. All the time we are discovering and developing new weapons and new methods, each of which can be traced back to some one, probably quite unknown to the world, in a laboratory or a drawing office.—*Viscount Halifax, British Ambassador to the United States, in an address at the Founder's Day celebration of the Carnegie Institute of Technology.*

BOOKS ON SCIENCE FOR LAYMEN

NEW PATHS IN GENETICS[1]

THE geneticist must endeavor to become a jack-of-all-trades, according to Professor Haldane in the introduction to this series of lectures given at the University of Gröningen, Holland, in March, 1940. A geneticist must cultivate the keen eye of a morphologist for slight differences, the ability to apply the methods of a biochemist, the fund of knowledge of an anatomist, a physiologist and a pathologist. He must be something of a psychologist to deal with problems of behavior, and his studies of races perforce make of him a political scientist, an anthropologist and a taxonomist. He must understand both the techniques and the economics of agriculture, horticulture and animal breeding, he must be a statistician of ability, and on occasion he even becomes an historian. Not even Professor Haldane can encompass all this. The recital serves only to point out the rich relationships of the field of genetics, and to enlist the attention and interest of workers in these other disciplines, to whom the present lectures are primarily addressed.

The four lectures that follow the introduction are devoted to the relations of genetics and biochemistry, embryology and medicine, respectively, and to the development of formal human genetics. If there is little new to the geneticist in these discussions, Haldane nevertheless manages, as always, to provoke thought by the freshness of his point of view and the distinctive clarity of his expression.

Medical men and biologists in general can not fail to be interested in Haldane's discussion of the genetics of human metabolic aberrations, such as phenylketonuria, a recessive condition associated with idiocy or imbecility, or the lethal skin disease, xeroderma pigmentosum, in which all heterozygotes, although not red-headed, are intensely freckled.

The chemistry of gene-controlled flower pigments affords the most extensive illustration of the interlocking research of geneticist and biochemist. It is very interesting that the action of certain genes on the anthocyanin pigment molecule appears to be direct and simple. The molecule is oxidized, for example, at a particular position. This Haldane regards as comparable to the action of the blood group genes of animals, where each gene produces a specific blood antigen. Haldane is willing to speculate that such apparently direct relations may mean that the antigens or enzymes are the immediate products of the genes concerned. This is perhaps over-optimistic, for the directness and simplicity of the final step in a chemical series is by no means always an indication that the entire series is brief and simple. Yet to a biologist the hope that we may be able to study direct gene action is ever tantalizing.

In discussing the role of genes in development, emphasis is laid on the very complex and numerous consequences of a single gene variation. This emphasis serves to counterbalance the apparent simplicity of the biochemical studies previously examined. Grüneberg's studies of the effects, in rats, arising from a cartilage anomaly, and in mice, of the anemias associated with hair color and pattern, afford examples of the extraordinary variety of consequences that may depend upon a single genetic change. Such studies should attract the medical scientist. As Haldane says, "It is probable that all mice and all men carry genes

[1] *New Paths in Genetics.* J. B. S. Haldane. 206 pp. $2.50. March, 1942. Harper and Brothers.

which, in any existing environment, would cause their death after a sufficient number of years." To abolish the genes that lead to the hardening of our arteries and to other diseases of aging is a task not altogether impossible, but one that will no doubt require some hundreds of centuries.

The analysis of other human maladies is farther along. For example, Mongoloid imbecility, like polydactyly in guinea-pigs, is clearly associated both with the deteriorating prenatal conditions that accompany advancing maternal age, and with genetical factors. In this instance, Haldane clearly points out the common error of making a one-sided interpretation of human data. The "extreme eugenist" will place all his emphasis on the variation in incidence between families, the "extreme environmentalist" will consider only the increase in incidence with advancing maternal age.

Haldane further considers the problem of mental defect. He comes to the conclusion that ordinary hygienic measures might eliminate about 15 per cent. of it, and segregation or sterilization a like proportion, while the prevention of inbreeding would be of slight, although not entirely of negligible effect. Really to get at the root of the problem it will be necessary, he points out, "to find means of detecting irregularly dominant genes in individuals who are not defective, and recessive genes in heterozygotes." Actual examination to determine these types by detection of associated effects is one way to attempt this. Mapping the human chromosomes, as discussed in the final chapter, is another. Meanwhile, we can be occupied for the next century or so in classifying mental defects adequately and in working out their genetic bases.

Especially interesting is the demonstration that from a knowledge of the frequency of a gene in equilibrium in a population, and of its relative fitness, the mutation rate of the gene can be determined approximately. The normal alleles of the sex-linked recessive gene for hemophilia and of the autosomal dominant causing epiloia both appear to be mutating to their abnormal alleles at a rate of about one in 100,000 per generation. Autosomal recessive genes, however, are to a great extent not exposed to selection and so are nowhere near equilibrium in the population. This is particularly true in modern Europe, where the equilibrium has been upset in recent centuries by the decline of inbreeding. Recessive characteristics appear to be rare in western countries today because of this. We may expect, however, that the frequency of the recessive genes will increase, because of their additional protection from selection, and consequently the incidence of the conditions they determine will be slowly augmented in the future, unless we find some means of preventing it.

In short, although some of the new paths in genetics are scarcely discernible trails just at present, yet any reader of this book will readily be convinced that the enhanced physical and social welfare of our human species will depend upon their further exploration.

H. B. Glass

SCIENCE FOR AMERICAN YOUTH[1]

When a boy or girl first awakens to an interest in science he is always highly specialized. It is a particular bug or flower, a fascinating electrical effect or a special chemical reaction which occupies his attention to the exclusion of all else. For a time he can not be interested in any subject but that, even though to

[1] *Science Calls to Youth.* A Guide to Career-Planning in the Sciences. Raymond F. Yates. Illustrated. viii + 205 pp. $2.00. 1941. D. Appleton-Century Company.

an adult others seem very closely related. Gradually through the years and increasing study the interest of the youngster expands, but he usually reaches middle age before he has a broad interest in science as a whole. It is because specialization is thus inherent in the process of learning that even adult scientists have so little concept of the scope and the implications of their field of work.

Raymond F. Yates, now patent editor of *Modern Mechanics and Inventions* and formerly editor of *Television*, in this little book intends to supply an antidote and to widen the vision of youthful scientists with a description of the role of science in molding our world and its promise of a new civilization after the war. He argues eloquently that the age of science is yet to come and that our present travail is a glorious beginning, not a tragic end. He includes also chapters on the type of positions open to scientifically trained men and women and describes quite fully the educational plan at Antioch College and the science clubs for high-school students, that were sponsored by the American Institute of the City of New York at the time this book was written but are now conducted by Science Service.

The book contains many excellent full-page illustrations of the young scientists at work. They do not, in fact, illustrate the text but are in sharp contrast with it by showing boys and girls deep in their extremely specialized hobbies. Indeed, one who knows the work of children may well wonder whether the broad generalities of the text will appeal to them. Certainly every teacher of science should know and ponder the information given and the thoughts of the author. For that objective—and even for the youngsters—one could wish that the style were more mature.

GERALD WENDT

THE TECHNOLOGY OF RESINS[1]

SOME of the natural resins are obtained from living trees, but those used in the greatest quantities are fossilized. Hence the question of supply arises. Dr. Mantell and his colleagues (of the Netherlands Indies Laboratories, Brooklyn, N. Y.) assure us that the New Zealand deposits of Kauri, for example, will supply the demand for well over 100 years. They do not concern themselves, however, with the possibility of a sudden and enforced cutting-off of the supply. When it is considered that most of the natural resins stem from Batavia, Borneo, Macassar, Manila and Singapore, the desirability of even greater encouragement to the synthetic ones becomes apparent.

The authors' style is simple, direct, eminently readable. The layman will learn in a very satisfactory way how the following products are dependent upon one or more of the natural resins: Scotch tape, linoleum, printing inks, wrinkle finishes. There is a long discussion of the natural resin content of traffic paint and its influence on durability. Presumably we will have adequate traffic stripes again as soon as we get the rubber to erase them.

However, somewhat more than four fifths of the book is devoted to highly technical details. Numerous formulas for wax emulsions, polishes and varnishes are given, with complete directions for compounding. Table XIX, on the solubility, viscosity and color of natural resins, comprises twenty-four pages; the solvent actions of 131 solvents are dealt with.

Hence it must be reluctantly acknowledged that the book was not intended for the layman, but when one is written, these authors are hereby nominated for the job.

THOMAS B. GRAVE

[1] *The Technology of Natural Resins.* C. L. Mantell, C. W. Kopf, J. L. Curtis and Edna M. Rogers. Illustrated. vii + 506 pp. $7.00. 1942. John Wiley and Sons.

Official U. S. Navy Photograph

NEW NATIONAL NAVAL MEDICAL CENTER NEAR WASHINGTON, D. C.

THE CENTRAL TOWER IS 270 FEET HIGH, ONLY A FEW FEET LESS THAN HALF THE HEIGHT OF THE WASHINGTON MONUMENT.

THE PROGRESS OF SCIENCE

NATIONAL NAVAL MEDICAL CENTER

THE National Naval Medical Center was dedicated by the President of the United States on August 31, 1942, in a ceremony that commemorated the one hundredth anniversary of the founding of the Bureau of Medicine and Surgery. The new Medical Center is a fitting tribute to a century of progress in the care of the sick and wounded of the United States Navy. The professional standing of the American naval medical officer has always been an enviable one, and his skill and abilities have accurately mirrored those of the best civilian physicians of his generation. A century ago the American physician was an individualist who treated his patients to the best of his ability, without recourse to specialists or diagnostic centers. The day of specialization had not yet arrived. His contemporary in the Naval Service treated his patients, ashore and afloat, at home and in foreign lands, in the same manner. As medical knowledge increased, it became impossible for the physician to be proficient in all branches of his profession. Men specialized and eventually began grouping themselves into clinics and diagnostic centers, benefiting both their patients and themselves. This trend in the medical world was reflected in the Naval Medical Corps, and qualified officers were given special training in the specialties, and, thereby, the benefits of such specialization were extended to their naval personnel.

The duties and importance of the Medical Corps grew and kept pace with an expanding Navy. Naval hospitals within the United States and in outlying insular bases became clinics and diagnostic centers where naval personnel received medical care that was the equal of the best civilian institutions. The professional and administrative genius that guided and directed the far-flung medical activities of the Navy was the Bureau of Medicine and Surgery. On June 20, 1935, an order authorized the establishment of a Naval Medical Center in Washington, D. C. It was located at 23rd and E Streets, N.W., from the date of its organization until the occupancy of the new site.

The new Medical Center, known as the National Naval Medical Center, is located on a 265-acre tract of gently rolling Maryland land, one mile north of Bethesda and directly across the Rockville Pike from the National Institute of Health. Ground was broken on June 29, 1939, and the corner-stone was laid by President Roosevelt on Armistice Day, 1940.

The buildings are of structural steel, faced with pre-cast, exposed, aggregate-concrete panels. The style is monumental, with a central tower 270 feet in height. The use of dark spandrels, situated between the windows, creates the impression of massive square columns when the building is viewed from a distance. The front of the main building faces west, with the central tower flanked on each side by L-shaped wings, each with four floors. The main corridor extends back from the tower to the auditorium, which has a seating capacity of 600. Secondary corridors extend to the right and left of the main corridor, and communicate with two U-shaped wings with three floors and basement, in each of which are located six general wards.

The administrative offices are located on the first and second floors of the wings flanking the tower and in rooms opening off the main corridor. The operating suite on the second floor directly behind the tower is furnished with the most modern equipment. The main operating room is paneled with pink Tennessee marble and has two glass-enclosed view-

ing galleries equipped with sound devices for the transmission of the surgeon's voice.

The Medical Library contains, at present, more than 40,000 volumes, and has a total capacity of 70,000 volumes. On its shelves are many rare, old volumes dating from the seventeenth and eighteenth centuries. The library is under the supervision of professional librarians. There is a separate fictional library for the use of patients.

The Medical Center is composed of the Naval Hospital, the Naval Medical School, the Naval Dental School and the Naval Medical Research Unit. Each is a distinct administrative unit within the Center. The wards are situated in the U-shaped wings and in the tower. The floor plan of the tower above the fourth floor is that of a Geneva Cross. The fifth, sixth, seventh and eighth floors are general wards. The ninth to sixteenth floors, inclusive, are made up of rooms for one, two and four patients. The seventeenth and eighteenth floors are lounges, solaria and recreation spaces for patients. The x-ray department, on the fourth floor to the right of the tower, is completely equipped with the most modern diagnostic and treatment apparatus.

The Medical School occupies the entire third floor of both wings adjoining the tower. In it are located class and lecture rooms and the various laboratories. The Medical School is used for indoctrination of medical officers who recently have entered the Service and for the training of enlisted personnel in clinical laboratory procedures and in pharmacy and chemistry.

The Dental School occupies two floors of the north wing. It is furnished throughout with the most modern equip-

Official U. S. Navy Photograph

DEDICATION OF THE MEDICAL CENTER BY PRESIDENT ROOSEVELT

THE ONE HUNDREDTH ANNIVERSARY OF THE FOUNDING OF THE BUREAU OF MEDICINE AND SURGERY WAS FITTINGLY COMMEMORATED BY THE DEDICATION OF THE NEW MEDICAL CENTER.

Official U. S. Navy Photograph

A SECTION OF THE MEDICAL LIBRARY

THIS LIBRARY CONTAINS OVER 40,000 VOLUMES, SOME OF WHICH DATE BACK TO THE SEVENTEENTH AND EIGHTEENTH CENTURIES. THERE IS A SEPARATE FICTIONAL LIBRARY FOR PATIENTS.

Official U. S. Navy Photograph

A VIEW OF ONE OF THE MEDICAL WARDS

THE WARDS ARE SITUATED IN THE U-SHAPED WINGS AND IN THE TOWER.

ment. The Dental School is used to indoctrinate newly inducted dental officers, train dental technicians, provide clinical dental treatment for personnel, and carry out studies in dental research.

The research unit will occupy a separate building on the Medical Center reservation. This building will be commissioned and ready for occupancy about November 1, 1942. Here, trained personnel will carry on experimental work in physiology, particularly that dealing with atmospheric hygiene in connection with deep-sea diving and high altitude flying.

The secondary buildings of the center, including living quarters for the nurses and hospital corpsmen, five sets of officers' quarters, power-house, laundry, storerooms and garage, are constructed of materials and a style that harmonize with the main building. Considerable grading of the tract was completed before construction was begun, and landscaping of the site is progressing steadily. When the entire project is completed, the National Naval Medical Center will be a site of beauty and a lasting memorial to those who have planned and carried out its establishment.[1]

FREDERICK C. GREAVES, *Commander*
MEDICAL CORPS, U. S. NAVY

NEW RCA LABORATORIES AT PRINCETON

DEDICATION of the new RCA Laboratories at Princeton, N. J., on September 27 marked another step forward in the progress of scientific research and development.

The first laboratory of the Radio Corporation of America was located in a tent at Riverhead, Long Island. That was in 1919. From that small beginning its research facilities and staffs have undergone a process of evolution. They were developed as necessary adjuncts to the several different branches of its business —world-wide and marine radio communication, domestic and international broadcasting and radio manufacturing. Consequently, its laboratories have in general been located at or near its various communication centers, factories and offices where such activities have been conducted. Some of the laboratories have occupied space in plants designed primarily for manufacturing rather than for research and experimentation.

There were two main reasons for the erection of the new laboratories: First, to provide increased facilities specially designed for scientific research and original development work. Second, to make possible the centralization of closely related research activities and their staffs. Demands created by the outbreak of the war increased the desirablity of the move and expedited the plans and construction, as indicated by the fact that ground was broken for the laboratories on August 8, 1941, and the cornerstone was laid on November 15, 1941, three weeks before Pearl Harbor.

The nature of the work required a site large enough to provide effective insulation for the main laboratories from electrical and mechanical disturbances, as well as to provide adequate space for conducting outside radio tests, for the erection of outlying buildings and other structures, and for future expansion. Accordingly a site comprising about 260 acres of farm land was acquired on the edge of Princeton because of its accessibility by the main line of the Pennsylvania Railroad from the principal offices and plants of the company in New York, Camden, Harrison, Indianapolis and Lancaster. It is also adjacent to excellent residential localities from which it can be reached by good roads.

Also, not the least of the attractions

[1] Opinions or assertions contained herein are the writer's and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

of this area is its inspiring atmosphere, which is so conducive to creative and original work. The state and community are rich in history. The site itself is part of a tract acquired in 1693 by William Penn and is adjacent to a small settlement named "Penn's Neck." Many of the neighbors are institutions and organizations devoted to education, culture, science and research. They include Princeton University, the Institute for Advanced Study, Rockefeller Institute for Medical Research and Walker Gordon Laboratories. The large tract and the necessity for the placing of the laboratories well within it—away from highways and railroads—provide a setting that lends itself to landscaping which will add greatly to the attractiveness of the laboratories.

The design of the buildings is essentially functional. The objective was to attain harmonious utility, simplicity and dignity in architecture. The main practical requirements were for a structure which would provide scientists and engineers with every facility for research and experimental work and for a fully equipped shop in which to make models of experimental apparatus.

The present buildings comprise a main laboratory wing 488 feet long, an intermediate laboratory wing extending 108 feet rearwardly from the center of the main wing, and a shop building, 152 by 182 feet, at the rear of the intermediate laboratory wing.

The laboratory wings are three stories in height with basements. In effect, these wings are built around the electrical, water, gas, air, drain, ventilating and other services required for the conduct of a wide range of electrical, physical and chemical research work. The mains for these services are suspended from the basement ceilings and run lengthwise and centrally of the laboratory wings directly beneath the central corridors on the floors above. The basement also contains transformers, motor generator sets, regulators and air-conditioning apparatus. Thus, the basement is the nerve-center of the laboratories.

Around each steel column on both sides of the corridors in the main laboratory wing are vertical ducts—104 of them—extending from the basement to a penthouse on the roof. Branches are tapped off the mains in the basement and are carried upward through the ducts to the rooms in the laboratories where services are required. The ducts have transite panel sides which are readily removable on all floors to provide complete accessi-

BUILDING OF THE NEW RCA LABORATORIES AT PRINCETON, N. J.

ONE OF THE SPACIOUS LABORATORY ROOMS

EACH LABORATORY HAS BROAD DAYLIGHT EXPOSURE SUPPLEMENTED BY MODERN INDIRECT LIGHTING, WHICH CASTS NO SHADOWS. NOTE THE DUCTS, WITH REMOVABLE PANELS ALONG THE WALL, THROUGH WHICH ELECTRICITY AND OTHER SERVICES ARE FED TO THE WORK BENCHES. FROM THE ELECTRIC OUTLETS ATOP THE BENCHES, ALMOST ANY PHASE OF ELECTRIC CURRENT AT VARIOUS VOLTAGES IS AT THE FINGERTIPS OF THE RESEARCH WORKER.

bility to the enclosed vertical branches from the service mains.

Horizontal extensions are carried from these branches to 420 specially designed laboratory benches each 6 feet long. The electrical services are enclosed in a wiring trough that extends along the tops of the benches and that has panel outlets each of which is marked to show the character of current available from it; *i.e.*, whether AC or DC, its frequency voltage, etc. There are taps on the benches for gas, water and compressed air, as well as for hydrogen and oxygen where they are needed. The drains from the laboratory benches are also run down the vertical ducts, and the ventilating flues from the benches and hoods are carried upward through the ducts to the penthouse where individual blowers exhaust them to the outside.

These distinctive features provide great flexibility for arranging and rearranging the laboratories at any time for any desired class of work or use without disturbing floors or walls.

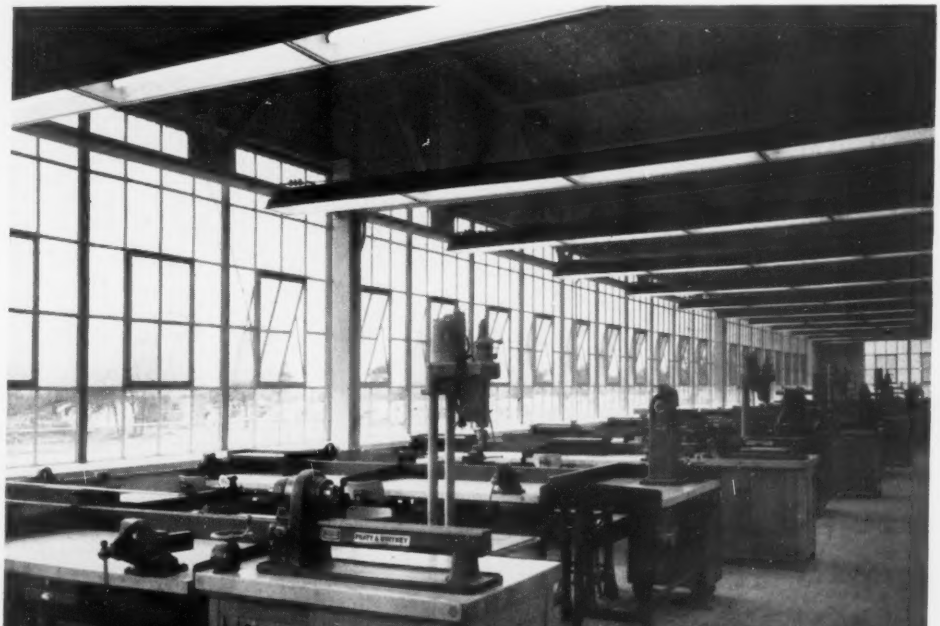
Some of the outstanding features of the main laboratory wing are a modern two-story television studio, a three-story free field sound room the walls of which are lined with heavy baffles or curtains of ozite so that no extraneous sounds of any kind are heard, a dust-free air-conditioned chemical laboratory especially designed for the study of fluorescent materials, an air-conditioned electron microscope laboratory and a unique optical laboratory. Other laboratories are provided for research pertaining to centimeter wave transmission and reception, receiving, transmitting and cathode-ray tubes, radio facsimile, acoustics and to other subjects associated with the future of radio and electronics.

The intermediate wing of the laboratories will be used temporarily for of-

fices, and therefore has not yet been equipped with vertical ducts and a penthouse. However, removable floor and roof slabs have been provided around each of the columns along the sides of the corridors, so that this wing can be readily converted to laboratory use at any time.

The shop building is a conventional one-story factory type of structure without basement. The model shop in the rear portion of this building is fully equipped with the most modern machinery so that every kind of operation can be performed in the making of models. This building also contains a drafting room, a meter calibrating and storage room, photographic and blue print rooms, a fireproof vault and a kitchen and cafeteria. Temporarily it also houses the library and conference rooms which it is planned to move into buildings to be erected in the future.

In addition to the main buildings the project includes a boiler house, a remote radio laboratory, a spring-fed pool and an adjacent laboratory for under-water sound work, a water supply system including two artesian wells having a combined capacity of 600 gallons per minute, a system of storm and septic sewers, and entrance and other roads. Electrical, gas and telephone services are furnished by the local utilities and are installed underground. Virgin farm land has thus been converted into a complete settlement capable of extensive further development.



THE MODEL SHOP OF THE RCA LABORATORIES

ITS OPERATIONS RANGE FROM GIANT PUNCH PRESSES TO GAUGES ACCURATE TO 5 MILLIONTHS OF AN INCH. MILLING MACHINES, DRILLS AND LATHES ARE LOCATED CONVENIENTLY TO THE WORK BENCHES.

Plans have been prepared for the future erection of additional laboratory wings as required and for an office building for administrative, patent and related staffs. The office building will be located in front of the present main laboratory wing and will contain the front entrance and lobby which will be reached by a diagonal drive from the New York to Philadelphia highway.

These laboratories are not intended as an effort to pre-empt the field of radio and electronic research. In science, as in everything else, competition is the greatest spur to healthful activity. In the alliance of science with modern industry both individual inventors and organized research groups are needed. Each has its field. The flame of some men's genius burns brightest alone. Many of the greatest inventions have been made by individual scientists, with primitive equipment and with little or no help, save the inspiration of their own unquenchable spirits.

But there are many inventions that could never be made and developed in that way. They call for systematic research, and for organizations of men, of materials, of equipment, of resources. The workers in these modern and efficient laboratories will have at their command all these essential factors. They will also have a valuable association with the communications, broadcasting and manufacturing services of the Radio Corporation of America. These services will be sources of ideas for development as well as of problems for solution. They will also be proving grounds for testing inventions and new devices in actual service and production. And the inventions that crystallize here will also be available under licenses to the whole radio and electronic industry.

When the war ends these laboratories will stand dedicated in advance to serve the cause of a victorious peace. For therein lies the distinctive characteristic of scientific endeavor. Its destructive power is one of the greatest weapons of war, and its constructive power is one of the greatest assets of peace. The same radio and electronic discoveries which these and other laboratories will have forged into weapons to tear down the ramparts of our enemies will also serve to rebuild the structures of our peace.

Because men work to-day in laboratories like these, new cities will rise from the ruins of the silent battlefields, richer crops will be harvested from the black stubble of scorched earth, and finer homes—richer at least in material things—will replace the homes that have been devastated by war.

The triumphs of science warrant our saying—amid all the horrors of war—there is still hope for civilization.

To help make that hope come true is the purpose to which these new laboratories have been dedicated.

Otto S. Schairer, Director

FIREARMS EXHIBIT AT THE U. S. NATIONAL MUSEUM

The firearms section of the special exhibition now on display in the U. S. National Museum, which because of limited space includes only a small part of the National Collections, is intended to show the major changes that have taken place in firearms during the last three centuries.

The collection includes a number of original patent models, most of which were not practical, but many of which were decidedly ingenious. Matchlock, wheellock and miquelet lock pieces are shown—among the latter two very ornate pieces presented by the Sultan of Morocco to Thomas Jefferson.

For comparative purposes a model of the 1800 U. S. Military musket is shown beside a Garand Ml rifle, the present weapon of our fighting forces. A double-barrel flintlock fowling piece was formerly owned by General Wade Hampton,

FIREARMS OF THE PAST AND PRESENT AMERICAN FORCES
Upper: U. S. MILITARY MUSKET OF 1800. *Lower:* GARAND M1 RIFLE, THE PRESENT WEAPON OF OUR FIGHTING FORCES IN WORLD WAR II.

who served in the American Revolution and the War of 1812. With this piece is shown an auto-loading shotgun of the present day.

In the display will be found specimens of the "Brown Bess," the official musket of the British Army in the war of the Revolution, and the "Charleville," a musket of the type brought over from France by Lafayette and presented by him to the American Colonies. This Charleville musket was considered in its day the highest type military arm in the world and was the model from which our first United States muskets were made.

The model 1800 rifle was the first rifle made in United States armories for the equipment of "a rifle regiment," authorized by an Act of Congress in 1799. The "Hall" breechloading musket with its various modifications, the first breechloader adopted by the U. S. Army, was invented by John H. Hall in 1811.

Among the multi-shot pieces are the Porter, a rifle with a cylinder of nine radial chambers which are successively aligned with the bore by a movement of the trigger-guard; the Colt revolving cylinder similar to the Colt revolver; and the "Lindsey," a percussion musket which fired two superposed charges loaded one on top of the other. In this last piece the bullet of the rear charge was intended to act as a gas check and

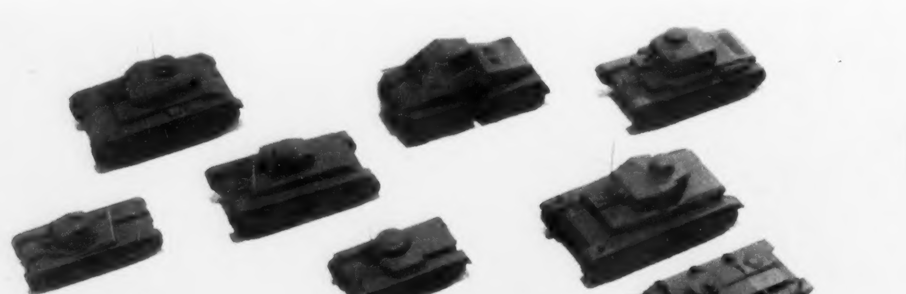
OLD FOWLING GUN AND MODERN SHOTGUN
Upper: DOUBLE-BARRELED FLINTLOCK FOWLING PIECE OWNED BY GENERAL WADE HAMPTON, WHO SERVED IN THE REVOLUTION AND THE WAR OF 1812. *Lower:* AUTO-LOADING SHOTGUN OF TO-DAY.

MODELS OF AMERICAN TANKS OF THE PRESENT DAY

breech for the front charge. A repeating pill-lock rifle formerly owned by General Sam Houston, president of the Republic of Texas, is shown. The magazine of this piece is a rectangular block with five chambers which moves horizontally across the breech of the barrel, actuated by the movement of the trigger.

Several cases of modern sporting arms are shown, as well as military rifles, machine rifles and machine guns, and also the shoulder arms of Allied and enemy countries in World War I. The machine guns and rifles include Colts, Vickers, Brownings, the Lewis, Hotchkiss, Mondragon, St. Ettienne, and others.

Pistols and revolvers are shown, dating from the earliest hand cannon, the pistol of the American Revolution, early Colts, pepper-boxes, and others, including the automatic pistols of the present day. One very ingenious piece shown is



MODELS OF GERMAN TANKS USED IN THE PRESENT WAR

the "Mortimer," a flintlock pistol which by a movement of a lever placed a ball in the barrel, filled the chamber with powder and charged the pan with priming. For each movement of the lever a shot could be fired.

Handsome scale models of the 14-inch naval guns used by the navy ashore in France, a model of the 7-inch field gun used by the Marines in France in World War I, and twelve scale models of German Army tanks, and sixteen scale models of American tanks and armored vehicles being used in the present war are included in the exhibit.

CHARLES CAREY

WALTER LOWDERMILK CALLED AGAIN TO CHINA

IN the summer of 1941, before Pearl Harbor, the United States Government received an urgent request from China. Japan had forced some 65 million Chinese from the smoother lowlands of the coastal country back into the rough lands of the interior. Food for the armies and people of Chiang Kai-shek had to be produced on steeper and steeper slopes. Under cultivation the soil was washing from beneath the warring nation. Erosion was sapping the life blood of continued national resistance. The Chinese Government wanted Walter Lowdermilk to come to China and lead the fight against erosion—a foe as relentless and as deadly as the Japanese.

Before Lowdermilk could complete plans for departure he was stricken by a desperate illness. After months in the hospital he was released with the warning that strenuous exertion of any kind would probably have disastrous results. Lowdermilk, however, had fought for civilization in World War I. He had later spent many months in China helping to stave off the frightful effects of famine. So long as there was a spark of energy left in his body he would continue to work for the betterment of mankind, completely oblivious to his own personal interests or welfare.

It was under these conditions that Walter Lowdermilk left for the Orient early in September of this year, accompanied by Dr. Theodore P. Dykstra, of the Bureau of Plant Industry, a specialist in corn and potato breeding.

During his previous stay in China he had learned what it means to a nation to strip its land bare of forest and expose the good earth to the ravages of erosion. It was more than a call to duty that prompted him to undertake the perilous journey, much of it over submarine-infested waters and through skies in which enemy aircraft lurk constantly. He left with the conviction that he could help save a great civilization.

Before his illness, Lowdermilk had nearly completed a survey of that ancient part of the world along the shores of the Mediterranean across north Africa to Syria—through desert, desert-border and lands laid waste by erosion—when World War II struck. He went at the urgent request of former Secretary of Agriculture Henry A. Wallace and myself to see what had happened to the agricultural lands in that part of the old world as the result of man's use of the land across the ages. He returned with heart-rending revelations and a wealth of information showing how civilizations have vanished from this earth as the result of raids, wars and exploitive use of the land. He found the remains of cities, the very names of which are lost to man in the debris of eroded soil—soil that made it possible to build the cities.

Lowdermilk returned to the United States resolved anew to help his fellowmen, regardless of race or creed, to avoid the loss of their productive lands. Never in all my forty years of public service have I known a man—private citizen or public servant—more completely determined to put the interests of humanity

ahead of his own personal desires and well-being.

The request from the Chinese Government called first for a specialist to direct the manufacture of insecticide and fungicide, a specialist to operate a laboratory for the manufacture of livestock serums and vaccines, and a plant breeder for corn and potatoes. Subsequent requests have been made for a teacher of animal husbandry, an animal breeder and a hydraulic engineer. The country is being searched for right men to fill these assignments.

HUGH H. BENNETT, *Chief*
SOIL CONSERVATION SERVICE

ERSATZ IN 1942

STEADILY during the years from 1914 to 1919 the word *Ersatz* came to be associated more and more with crude vegetable fiber and even the bark of trees as substitutes for digestible human food, and with paper and paper products as substitutes for cotton, silk and wool in clothing; it called up specters of hunger, malnutrition, starvation, cold, misery and death.

In 1942 the English equivalent "substitute" has suddenly acquired entirely different connotations. Instead of implying the inferiority of that to which it is applied, it generally carries the promise of inexhaustible new sources of substitutes that are often better than the original materials. Instead of suggesting suffering, it promises comforts.

No sudden shortage of material has affected the general public more acutely than that of rubber. The recent scarcity of rubber has forced the development of substitutes made from various abundant available materials that even at this early period are superior to the natural product in some important respects. A new era in the equivalents of rubber appears to be opening.

One of the essential materials for modern life, in peace and war alike, is steel. The various kinds of steel are not pure iron but alloys of iron with copper, nickel, chromium, cobalt, manganese, vanadium and other elements, in various combinations. The shortage of steel-producing capacity to meet the enormous demands of war and the lack of adequate domestic supplies of certain alloying materials, such as nickel, has stimulated the development and use of "low alloy" steels for structural purposes that will result in enormous advantages. For example, in the production of the 270,000 freight cars that are now needed there will be a saving of a million tons of finished steel, four million tons of raw materials for its making, and enormous amounts in rail and water transportation. There are, however, indispensable alloys using imported metals for which substitutes do not yet exist.

The use of Cellophane for wrapping and protecting foods is so recent as yet to be regarded as almost miraculous. A somewhat analogous development is that of plastics to displace steel and wool for hundreds of purposes, ranging from rough packing cases to furniture and to certain works of art. The raw materials of which plastics are made fortunately are abundant and widely available.

Lest it be assumed that there are fairly satisfactory substitutes at hand or foreseen for every material now used by civilized men, one element should be mentioned that appears to be almost, if not quite, indispensable for very important purposes. It is of more importance than all the gold buried in Kentucky, than all the diamonds that are used as ornaments or the cutting points of tools. It is silver. For what is silver uniquely used? The answer is for photography, and hence indirectly for all the science and art and records and industry that depend upon it. Fortunately silver is widely distributed over the surface of the earth in quantities abundant for the uses of photography.

F. R. M.